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A COMPARISON OF ORAL, AXILLARY, RECTAL, AND TYMPANIC MEMBRANE TEMPERATURES OF INTENSIVE CARE PATIENTS WITH AND WITHOUT AN ORAL ENDOTRACHEAL TUBE

BY

ELSIE KONOPAD

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF NURSING

FACULTY OF NURSING

EDMONTON, ALBERTA

SPRING 1990

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SUBMITTED BY ELSIE KONOPAD

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ABSTRACT

It is common practice in critical care units to monitor rectal temperatures in orally intubated patients. It is believed that rectal temperatures (RTs) are more accurate than oral temperatures (OTs). An experimental study, using patients as their own control, was used to compare OTs of patients in the intensive care unit (ICU), with and without an endotracheal tube. A secondary purpose of the study was to compare axillary (AT), tympanic membrane (TMT), and rectal temperatures (RTs) of patients with and without an oral endotracheal tube. Sixty-five orally intubated patients with a physician's order for extubation, were considered suitable for entry into the study. The patients ranged in age from 17 to 96 years; 17 were female and 48 were male. The average APACHE score was 19.5 $\pm$ 9.3. Following consent to participate, patients had oral, axillary, rectal, and tympanic membrane temperatures taken, after which they were extubated. The patient's temperature measurements were repeated following a standardized stabilization period. Using a t-test for paired samples, a significant difference was found between both ATs and OTs measured with and without an oral endotracheal tube ($p<.01$), however the difference (-.12 and .08^{o}C, respectively) was not considered clinically important. Further t-tests for paired samples revealed no significant difference between the TMTs and RTs pre and post extubation. Respiratory rate, presence or absence of teeth, and mouth position were shown to have no affect on the OT, using t-tests ($p>.01$). Analysis of variance was used to determine if room temperature or temperature within the endotracheal tube had an affect on OT; no effect was found. It was concluded that OTs are accurate when taken in patients who are

orally intubated and ready for extubation. In addition, the reliability and validity testing of the thermometer, the biographical characteristics of both the patients entered and those not entered into the study are described. Limitations and clinical implications of the findings are discussed and recommendations for further research are presented.

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IVAC Canada:	IVAC® 8200 thermometer
Mallinckrodt:	Hi-Lo Temp® thermometer/probes
Intelligent Medical Systems, USA:	FirstTemp® thermometer/probe covers

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CHAPTER I

STATEMENT OF THE PROBLEM

Temperature monitoring, as an aid to diagnosing and treating disease, has been recognized since the late 1800's, and is one of the most frequently assessed physiological parameters by nurses. Temperature assessment is based on determining the core temperature of the body. However, temperature varies from one part of the body to another and it is difficult to measure true core temperature. The majority of temperature recordings made are only an approximation of the core temperature. In the clinical situation, temperature measurements are made in accessible locations near large arteries carrying blood which reflects the core temperature. Historically, the three most accessible sites for monitoring temperature were the mouth, axilla, and rectum. The decision as to which site to use was based largely on beliefs about the relationship between temperature and the patient's condition, as well as convenience, rather than on scientific knowledge.

Over the years there has been much debate as to the most "accurate" site for monitoring core temperature. Sites most frequently used for monitoring temperature have included the mouth, axilla, rectum, esophagus, and more recently, the tympanic membrane. It is common practice in critical care units to measure patients' temperatures rectally. The assumption is made that RTs, especially in orally intubated patients, are more accurate than temperatures taken orally. This notion is grounded on the presumption that orally intubated patients are unable to form a tight seal around the thermometer, rendering the recordings inaccurate. A question which arises is whether or not a tight seal

is necessary for an accurate assessment of OT. In several studies in which electronic thermometers were used, there was no clinically important difference between oral temperatures when the mouth was open compared to when the mouth was closed (Cooper & Abrams, 1984; Erickson, 1976).

Various types of thermometers have been used to measure body temperature, with glass-mercury and electronic being the most common. Electronic thermometers (ET) have been shown to be as accurate as, or superior to, glass-mercury thermometers (Erickson, 1980; Knapp,1966; Pugh Davies, Kassab, Thrush & Smith, 1986; Shanks, Lambourne, Morton & Sanford, 1983). The use of electronic thermometers may obviate the need to inflict the inherent discomforts and risks of RT monitoring on intubated patients in the intensive care unit (ICU).

Measuring body temperature is an integral part of the basic nursing assessment used frequently in the ICU. Site selection is often based on personal preference, with little scientific knowledge, and the task carried out habitually. Research exists comparing temperatures monitored at various sites in various combinations. Only three studies could be located comparing temperature recorded at various sites in intubated patients, and only one of these directly examined the relationship and made comparisons in intubated critically ill patients.

Purpose and Hypotheses

The primary purpose of this study was to compare oral temperatures (OTs) of patients in the ICU, with and without an oral endotracheal tube. A secondary purpose was to examine the comparisons and relationships among temperatures as

recorded from commonly used temperature monitoring sites. Sites that were examined were the mouth, axilla, rectum, and tympanic membrane.

Hypotheses

1. Using an electronic thermometer, patients in an ICU will show no difference in OTs, whether or not there is an oral endotracheal tube in situ.
2. Using an electronic thermometer, patients in an ICU will show no difference in temperatures as recorded by axilla, rectum, or tympanic membrane, whether or not there is an oral endotracheal tube in situ.
3. There will be a positive relationship between temperatures recorded from the mouth, axilla, rectum, and tympanic membrane, in patients in the ICU.

Definitions

For the purposes of this study, the following definitions were used:

1. Patient in Intensive Care: A patient, admitted to ICU, who was orally intubated and had a doctor's order to be extubated.
2. Oral temperature (OT): The temperature obtained by placing the oral probe of an IVAC^{R} electronic thermometer, using the slow slide technique (Erickson, 1976), into the posterior sublingual pocket, opposite to the endotracheal tube. To do this, the probe was inserted at the gum line, behind the lower central incisors and slowly slid along the gum to the back of the mouth, taking four to five seconds to reach the posterior sublingual pocket. (This facilitated prewarming of the probe.) The thermometer was placed in monitor mode and left in place until the

temperature displayed remained constant for one minute.

3. Posterior sublingual pocket: The area where the base of the tongue joins the floor of the mouth.
4. Rectal temperature (RT): The temperature obtained by placing a well lubricated rectal probe of an IVAC^{R} electronic thermometer into the anal canal, along the rectal wall, to a depth of two inches. Insertion took four to five seconds. The thermometer was placed in monitor mode and the probe left in place until the temperature displayed remained constant for one minute.
5. Axillary temperature (AT): The temperature obtained by placing a probe of an IVAC^{R} electronic thermometer 2.5 to 4.5 centimeters from the anterior margin of the axilla, along the axillary fold, on the side opposite to the endotracheal tube. The upper arm was held against the side of the chest, while the probe was in place. The thermometer was placed in monitor mode and the probe left in place for a minimum of nine minutes (based on Nichols, Ruskin, Glor, & Kelly, 1966). The temperature displayed was to remain constant for one minute prior to recording the temperature measurement.
6. Tympanic membrane temperature (TMT): The temperature obtained by placing the probe of a FirstTemp^{R} thermometer into the external auditory canal. The probe remained in place until the audible tone indicated that measurement was complete.
7. Continuous tympanic membrane temperature (CTMT): The temperature obtained by placing a probe of the Hi-Lo Temp^{R} thermometer into the

external auditory canal of the ear opposite to the endotracheal tube. The probe was taped in place and the ear covered with gauze.

8. Thermometer:

I. The IVAC^{R} (Model 2080) predictive electronic thermometer, calibrated and registering to the tenth of a degree in Celsius was used to obtain all oral, axilla, and rectal temperatures. All temperatures were obtained with the thermometer in monitor mode. The thermometer's range, in monitor mode, as reported by the manufacturer, was 26.7 to 42.2^{o}C, with an accuracy of $\pm$ 0.2^{o}C.

Steady State: Mode in which the thermometer calculates the curve of heat rise reflected in the current flow through the thermistor, anticipates where the final reading will be, and displays this prediction.

Monitor Mode: Mode in which the thermometer reads the temperature continuously and directly after coming into equilibrrium.

II. The FirstTemp^{R} (Model R000A) thermometer, calibrated and registering to the tenth of a degree in Celsius was used to obtain the tympanic membrane temperatures. The thermometer's range, as reported by the manufacturer, was 21.1 to 43.3^{o}C, with an accuracy of $\pm$ 0.2^{o}C.

III. The Hi-Lo Temp^{R} (Model 8200) thermometer, calibrated and registering to the tenth of a degree in Celsius was used to measure the tympanic membrane temperature continuously. The thermometer's range, as reported by the manufacturer, was 0 to 50^{o}C, with an accuracy of $\pm$ 0.1^{o}C.

Assumptions

Prior to initiating the project it was important that assumptions underlying the proposal be identified. The most basic assumption that was made was that core temperature is an important physiological parameter to monitor in patients in Intensive Care. It is believed that temperature registered in the central veins and large arteries is reflective of core temperature. The variation in temperature of local blood at each site was believed to be related to variation in central blood temperature, and therefore, it was assumed that oral, axillary, rectal, and tympanic membrane temperatures would be reflective of core temperature and that continuous tympanic membrane temperature would be the most reliable index of a true change in core temperature over time. To determine if OTs were accurate in patients with or without an oral endotracheal tube, it was essential to assume that the presence of an endotracheal tube did not affect core temperature. Any affect on OT would be through a local effect, and not an effect on the core temperature. Based on the research conducted, it was assumed that electronic thermometers were more accurate than glass thermometers in monitoring temperature, and that the self-calibration function of the electronic thermometers was accurate.

CHAPTER II

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

In order to examine the nursing practice of assessing body temperature, it is important to understand what normal body temperature is and how it is regulated. Knowledge of factors affecting body temperature and clinical importance of monitoring temperature are essential. When deciding how to measure body temperature, the nurse must take into consideration criteria for site selection, factors that affect temperature measurements at each site, and the instrument used to measure temperature. This chapter discusses the conceptual framework that this study is based on and literature published in the area of temperature monitoring.

Conceptual Framework

The conceptual framework used for this study is based on physiological theory and represents a combination of clinical and theoretical knowledge (see Figure 1). Following an introduction on normal body temperature, temperature regulation and set point will be discussed. Mechanisms for, and factors affecting heat production and loss, as well as the effect of an oral endotracheal tube on oral temperature will be addressed. The method and clinical importance of monitoring temperature will conclude this section.

Normal Body Temperature

International practice recognizes 37°C (98.6°F) as the "normal" body temperature. There is, however, no specific temperature applicable to all individuals as normal, and 37°C represents an average of the normal, oral

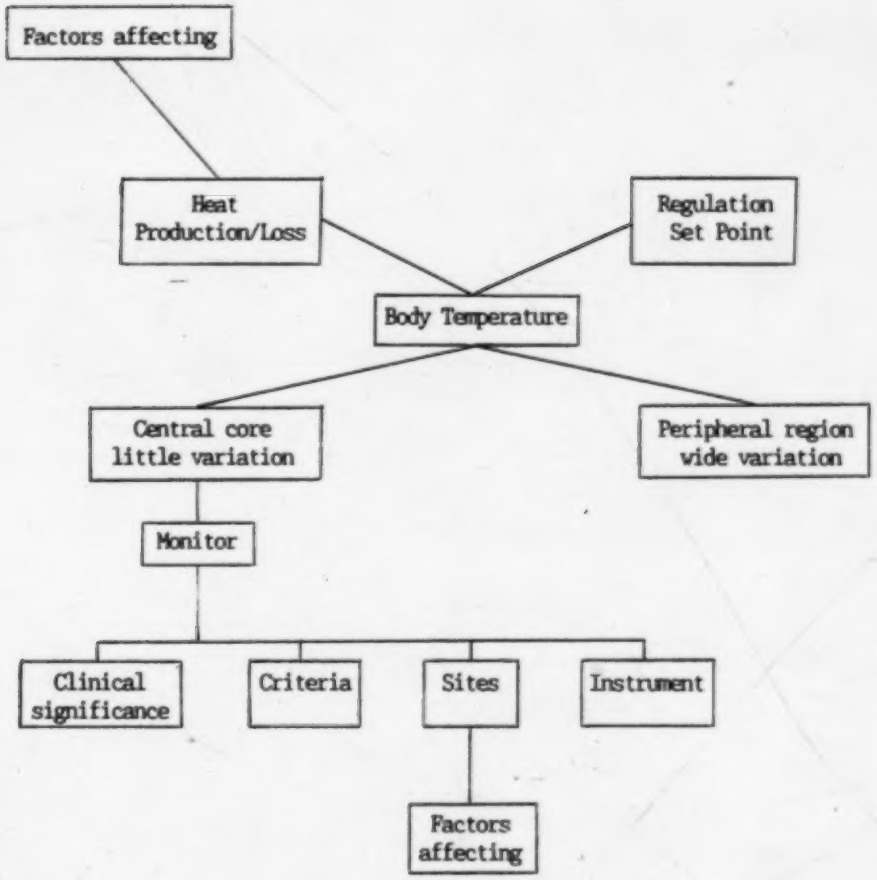

Figure 1. Conceptual framework.

temperature for resting man in the range of 36 to 37.5°C (Dubois, 1951; Sims-Williams, 1976). As well as there being no such thing as a "normal" temperature, there is no such thing as "a" body temperature. Temperature varies considerably from one part of the body to another. For simplicity, the human body is believed to consist of a central warm core (structures in the head and trunk), within which the temperature varies between narrow limits, and a peripheral region throughout which there are various temperature gradients (Cooper, 1969; Dubois, 1951). Core temperature (head and trunk) remains relatively constant and is determined by three factors: local heat production, insulation from environment and temperature and flow of blood supply (Cranston, 1966). Peripheral and skin temperatures vary, according to relative distance from the trunk or large arteries. Temperature registered in the central veins and large arteries, may be reflective of the core temperature (Eichna, Berger, Radar, & Becker, 1951).

Temperature Regulation

In humans, temperature is maintained within limits of approximately $\pm$ 0.2°, despite wider variations in environmental temperatures. Temperature maintenance is regulated by both behavioral and physiological mechanisms. Behavioral mechanisms include responses of the skeletal muscle to heat or cold, which modify the rate of heat production and heat loss. Examples of this include exercise, changing clothing, and moving to a warmer/cooler environment. Physiological regulation is controlled essentially by the Central Nervous System (CNS). The CNS integrates signals coming from the peripheral and central thermoreceptors, and if necessary, triggers appropriate mechanisms to

correct temperature imbalance (Benzinger, 1959, 1960; Benzinger, Pratt, & Kitzinger, 1961; Hardy, 1961; Holdcroft, 1980; Houdas & Ring, 1982).

Two levels are involved in temperature regulation: 1) thermoreceptors that are sensitive to temperature variations, and 2), thermoregulatory centers that integrate incoming signals from the thermoreceptors, and trigger the appropriate mechanisms (Benzinger, 1960, 1961a, 1961b; Benzinger, Pratt, & Kitzinger, 1961; Hardy, 1961; Houdas & Ring, 1982). Thermoreceptors are located peripherally in the skin and centrally in the body core. Peripheral thermoreceptors are sensitive to their own temperature and send signals to the CNS. They provide conscious perception of environmental temperature and stimulate the thermoregulatory centers to bring about appropriate behavioral and/or physiological responses. The majority of the central thermoreceptors are located in the CNS, in the anterior hypothalamus. These receptors respond by modifying their impulse discharges when their temperature is changed (Benzinger, 1960, 1961b; Hardy, 1961; Holdcroft, 1980; Houdas & Ring, 1982).

The main thermoregulatory center is located within the CNS, in the hypothalamus, although other parts of the CNS seem to have the capacity to generate thermoregulatory responses. The hypothesis put forward is that the anterior hypothalamus is responsible for sensing temperature, while the posterior hypothalamus is responsible for eliciting responses. Short term control of thermoregulation is initiated by nervous pathways, while hormonal factors play a role in long term alteration of the system (Hardy, 1961; Holdcroft, 1980; Houdas & Ring, 1982).

Set Point

It is generally agreed that the body regulates its temperature around a set point. The set point of the regulatory system is the temperature at which thermoregulatory responses are balanced. Any change in core temperature away from the set point initiates heat production or dissipation mechanisms. There is a normal diurnal variation in the set point and fluctuations in this rhythm can occur even when man is isolated from his environment. Certain diseases in man have been shown to cause the set point to shift, resulting in either hyperthermia or hypothermia (Cranston, 1966; Hardy, 1961; Holdcroft, 1980).

Heat Production and Heat Loss

Maintenance of body temperature results from a balance between heat production and heat loss. Heat loss from the body occurs by convection, radiation, and conduction. The amount of heat lost by these mechanisms varies, depending on environmental conditions. Heat is also lost from the skin and respiratory tract by evaporation. Evaporation is an important mechanism, and contributes approximately one quarter of the total heat loss under basal conditions in a moderately humid environment; sweating can cause a ten fold increase in evaporative heat loss (Holdcroft, 1980; Lomax & Schonbaum, 1979).

Mechanisms for heat production include basal metabolism, increased skeletal muscle activity, shivering, hormonal activity, and radiation and conduction. Basal metabolism forms heat which must be lost if body temperature is to remain constant. Heat is produced in the body, mainly in the muscles, liver and glands (Cranston, 1966). It is impossible to decrease heat production in the tissues to less than the basal metabolic rate. The main mechanism for increasing heat

production is through increasing skeletal muscle activity, either by voluntary action or shivering. Skeletal muscle makes up approximately 50% of body mass, and at rest contributes close to 20% of total heat production. During activity or shivering, heat production can be increased immensely. Cold stimulates the release of thyrotropin-releasing hormone from the hypothalamus, which has the end result of increasing the basal metabolic rate. Heat production can also occur from the absorption of energy from surroundings (radiation), and from ingestion of hot food/fluid (conduction) (Hardy, 1961; Holdcroft, 1980; Houdas & Ring, 1982; Lomax & Schonbaum, 1979).

Factors Affecting Heat Production and/or Heat Loss

Although central temperatures are more constant than those of the skin and periphery, normal fluctuations occur as a result of individual circadian rhythms. Body temperature generally rises to a maximum in early evening and falls to a minimum in early morning. This rhythm is related to activities affecting metabolism, primarily muscular activity and food intake, but in contrast, is also evidenced in fasting subjects at complete rest. Circadian rhythm has also been reported as being related to sleep patterns and daylight (Conroy & Mills, 1970; Cranston, 1966; Hardy, 1961). Another cyclical variation in temperature is that produced by ovulation in women, although this may be obscured by circadian changes.

Several other factors identified as causing temperature to vary are digestion, activity, local heat/cold applications, and environmental temperatures (Houdas & Ring, 1982). Particular to patients in the ICU, intravenous fluids and blood products administered at room temperature or less,

have been documented to decrease body temperature (Kumucu, 1965; Roe, 1973). As well, fluid balance has been shown to affect body temperature. During dehydration, RT at a particular metabolic rate is higher than during a state of normal hydration, and lower during hyperhydration (Moroff & Bass, 1965). Medications (vasodilators and narcotics), that cause peripheral vasodilation can contribute to heat loss (Roe, 1973).

Clinical Importance of Monitoring Temperature

Extensive research into pathophysiology of fever has been reviewed by Cooper (1972). There is evidence that the ultimate cause of "fever" is the release of indigenous pyrogens from blood leukocytes which act upon the brain. Precise mode of action is unclear, but it appears contingent on raising the "set point" of control mechanisms. Since fever can be an early sign of common nosocomial complications in the critically ill patient, prompt detection is essential. Glev and Blacklov (1985) suggested that a reading of 38°C indicates fever and requires treatment. Of further clinical importance, especially for hypoxic patients, Benzinger, T. (1969a) reported that an increase of 0.01°C in body temperature results in an increase of oxygen consumption rate by 10% of basal metabolic rate. Since a large majority of patients in ICU have oxygenation problems, an increase in temperature could contribute to greater hypoxia. In contrast to fever, hypothermia is frequently seen in critically ill patients. At 36°C, accidental hypothermia may be suspected, and it is defined at 35°C (Curley & Irvin, 1985).

Treatment may be initiated or postponed depending on temperature. An increase in a critically ill patient's temperature is usually related to a

septic event. The following activities are often initiated following a reported increase in temperature: blood, sputum, urine, and wounds are cultured, intravenous/arterial lines are changed, antibiotics are administered, and surgery may be considered. In some cases, planned surgery may be postponed due to an increase in temperature. Further to initiating or postponing treatment, temperature is often a primary indication of successful or unsuccessful treatment. For example, if the patient with an increased temperature is taken to surgery for removal of a septic source, or antibiotics are administered, temperature becomes a measure of effectiveness of treatment. Lower subsequent temperature measurements suggest that treatment has been successful.

Affect of Oral Endotracheal Tube on Oral Temperature

Major arguments against monitoring OT in intubated patients in the ICU is OT's variability due to environmental influences (Holdcroft, 1980). It is believed that OT will not be accurate because the patient cannot form a tight seal around the thermometer due to the presence of the endotracheal tube. As well, air leaks from around the cuff of the endotracheal tube may cause further variability in the OT recorded, therefore reflecting environmental temperatures as opposed to the true core temperature. It is also possible that temperature of the gases flowing through the endotracheal tube may have a local affect on the OT recording.

Methods of Monitoring Temperature

Ideally, temperatures should be measured at the thermoregulatory site in the hypothalamus. For obvious reasons, this is not possible in man, and more accessible sites for temperature measurement must be used. The sensation of

warmth or cold is obtained when we touch an object which has a temperature different from that of our own skin. However, temperature sensitivity of the hand varies according to thickness of the skin, and is not accurate enough for clinical use (Bergeson & Steinfeld, 1974). For practical purposes in the clinical setting, measurements are made in accessible locations near large arteries carrying blood that reflects the core temperature, and where there is the least risk to the patient. Temperatures at the site selected should not be influenced by local blood flow or by environmental temperature changes. The most common sites are the mouth, axilla, rectum, and more recently the tympanic membrane (Benzinger, M, 1969; Blainey, 1974; Cranston, 1966; Eichna, Berger, Radar, & Becker, 1951; Holdcroft, 1980; Tate, Gohrke, & Mansfield, 1970).

Historically, RT has been deemed to be the most accurate reflection of core temperature and this belief is currently held by the majority of health care professionals working in ICUs. The rationale for this is based on immunity of RT to environmental influences and the fact that RT is usually the highest value of all commonly monitored sites (Cranston, 1966; Cooper, 1969). However, there is evidence that RT does not reflect rapidly changing core temperature; as well, it is suggested that RT recordings are influenced by thermometer placement and body position (Cranston, Gerbrandy & Snell, 1954; Gerbrandy, Snell & Cranston, 1954; Molnar & Read, 1974).

Literature Review

Literature concerning temperature monitoring practices in orally intubated critically ill patients was reviewed to summarize the state of existing knowledge and highlight unresolved issues. Only three studies could be located

that examined accuracy of oral temperature in intubated patients; one of these involved critically ill patients. Other areas of the literature searched included temperature monitoring, specifically looking at site (oral, axillary, rectal, and tympanic), factors affecting temperature monitoring, and instrumentation (glass and electronic thermometers).

For the purpose of this review, a comprehensive survey of empirical works was conducted. Studies were identified by computer search from 1966 to 1989 and by manual searches of reference lists and literature in nursing and other health related fields from 1933 to 1989. Criteria for inclusion in this review were that it: (a) be an evaluative study citing temperature monitoring, factors affecting temperature monitoring or instrumentation, as an independent variable, (b) be systematic, (c) include information on the method and procedures for data collection, (d) present findings, and (e) be written or translated into English. Personal accounts were included only if they involved reporting hazards related to temperature monitoring. Review articles and theoretical manuscripts were utilized for background information only, and works reporting research in progress were not included. Several comparative studies that failed to meet criterion (c) were excluded.

This review begins with a brief overview of the history of thermometry, followed by a discussion of major methodological issues and problems inherent in the research. Discussion of literature searched is categorized under two main headings, according to the major focus of the investigation: type of thermometer used and site (mouth, axilla, rectum, and tympanic membrane). This review concludes with a summary of existing knowledge of monitoring temperature in

critically ill intubated patients and highlights unresolved issues.

Core temperature is difficult to assess for reasons of inaccessibility, and therefore, the majority of temperature recordings made on the body are only an approximation. Development of suitable and efficient measuring devices has been a preoccupation of scientists for centuries, with varying degrees of success. Early thermometers were crude devices. In 1592, Galileo, an Italian mathematician, developed an "air thermoscope". This recorded a person's temperature by transmission of air through a tube from the mouth to a container of water. Following this, in 1625, Sanctorius, an Italian doctor, modified the same apparatus and for the first time, temperature was used to study disease. In 1654, Ferdinand II produced a liquid-in-glass thermometer and in 1714, Fahrenheit invented the mercury thermometer (Keezer, 1966).

Lancisi in 1715 was one of the first to maintain that physicians should familiarize themselves with the use of the thermometer and in 1745, Van Swieten pointed out that estimation of temperature by the hand was uncertain. In 1738, George Martine published "Essays and observations on the construction and graduation of thermometers". This was the first documentation of accurate observations on temperature of healthy man and animals. Martine's ideas were carried into practice in 1767 by James Currie who used thermometry to check results while treating typhoid fever with cold baths (Brock, 1972; Dominguez, Bar-Sela, & Musher, 1987).

By 1840 several clinicians had made and published valuable observations on temperature in disease. The connection between sickness and a rise in body temperature was firmly established in 1868 in a paper by Dr. K. Wunderlich

(Brock, 1972; Keezer, 1966). The thermometer was one of the first instruments of precision used to aid medical practice. Wunderlich used a thermometer approximately one foot long, which was left in the patients axilla for 20 to 25 minutes. Thermometers were introduced into an English hospital in 1866-1867 and were in general use by 1868-1870. Thermometers used in this time period were cumbersome: they were ten inches long and "so clumsy that they were carried under the arm, two in a case, as one might carry a gun" (Brock, 1972, p. 310).

In 1867 Allbut made a short clinical thermometer which was six inches long and was to be left in the axilla for five minutes. Since then the thermometer has become the widely used diagnostic instrument that we know today. It is interesting to note that electronic methods of registering temperature changes were developed as early as 1835 and were used frequently throughout the mid and late 19th century for scientific observations (Brock, 1972; Dominguez, Bar-Sela, & Musher, 1987).

Major Methodological Issues and Problems

The majority of temperature monitoring studies in the literature are limited by the fact that they utilize nonprobability sampling and normal, healthy subjects. There is no evidence to suggest that illness makes a difference in temperature monitoring, but likewise there is no evidence to suggest that it does not. Another limitation presented by most studies is related to age. The majority of studies used individuals between the ages of 20 and 60. There is evidence that the elderly have a lower normal temperature, although a study by Thatcher (1983) on 100 adults aged 60 to 94 found that distribution of temperature by age suggested no pattern, and variance in temperature was not

explained by age. Howell (1975) reported a correlation, r = .15, between age and OT, in 105 subjects between the ages of 61 and 100 years. These major limitations greatly decrease the generalizability of the results, especially to critically ill and aged patients.

To be included in this review, research results had to be presented. The studies met this criteria, however a large majority did not indicate statistical significance; when reported, it is noted. A large proportion of studies reported accuracy testing of thermometers before and after experimentation. Those studies that failed to report this, are noted. None of the studies using repeated measures documented information regarding intra-rater reliability as related to thermometer positioning.

Type of Thermometer

Widely used as the glass thermometer (GT) is, its accuracy has been questioned. Knapp (1966) compared two electronic thermometers (ET) with 12 GTs over a temperature range of 95° to 105°F and demonstrated significant errors in the GT when tested for accuracy (M error = 0.5°F); as temperature increased, error of the GT increased. Error of the ET never exceeded 0.15°F. (The reference thermometer was accurate to ± 0.05°C). Knapp (1966) concluded that the ET was superior to the GT.

Abbey et al. (1978) tested 212 GT for accuracy, discarding those that were inaccurate. 207 GTs tested were accurate and divided into two groups. Group one (n = 160) were used in the clinical situation for two months and then put into storage; group two (n = 47) were put directly into storage. The two groups were retested for accuracy at one month, two months, and eight months.

Regardless of usage, all thermometers were inaccurate after eight months.

Purintun and Bishop (1969) tested accuracy of 24 oral and 24 rectal GT. Even though by law, thermometers must be tested and have an accuracy reading of $\pm$ 0.2°F, an error rate of 0.4 to 1.6°F was discovered. Shanks et al. (1983) compared the accuracy of two ET and a GT. A total of 100 comparisons were made in twenty patients, leaving the thermometer in the patients mouth for two minutes. There was no significant difference between the temperature recorded by the two ET and GT. Pugh Davies et al. (1986) compared accuracy of GT and ET against a reference thermometer and concluded that both ET and GT were of equal accuracy (accurate to $\pm$ 0.2°C). Conflicting results may be due to sample size and type of thermometer used.

Baker, Cerone, Gaze, and Knapp (1984) compared ET and GT and time of monitoring OT in 24 normal afebrile subjects. Subjects were randomly assigned to order of treatment condition: GT and two minutes; GT and four minutes; ET and buzz signal; and ET and four minutes after buzz signal. The study reported that length of insertion time had a significant effect on the temperature reading, but that type of thermometer did not make a difference.

Moorat (1976) attempted to discover the most cost effective method of monitoring temperatures, by comparing disposable (DT), electronic and glass thermometers. The findings revealed that the ET was least expensive in terms of staff time and the GT was least expensive in terms of equipment. Overall, the ET was the least expensive and DT the most expensive. Moorat (1976) also tested accuracy of thermometers with 30 patients. The error rates were as follows: glass: - 0.18° to 0.15°C; disposable: - 0.10° to 0.15°C; electronic: - 0.13°

to 0.10°C. Stronge (1980) supported Moorat's conclusions regarding cost, in that ETs were quicker to record the temperature, thereby saving staff time, greatly decreasing the overall cost of temperature monitoring. In this day and age with rising health care costs it is very important to choose the most cost effective and efficient methods. While Moorat (1976) and Stronge (1980) examined the dollar costs, they neglected to examine one other major cost that we are facing today: environmental costs. When choosing equipment it is important to consider both accuracy and cost—cost in dollars and cost in terms of the environment—weighing the benefits of each.

Length of insertion time is an important factor in accuracy of temperature recording as already noted. Takacs and Valenti (1982) explored factors associated with temperature measurement in the clinical situation. They observed temperature monitoring on several different nursing units, on all three shifts. When GTs were used the time for temperature measurement was determined by the number of other nursing duties that were done, not by established protocol. Average thermometer insertion times were as follows; GT and OT: 2 minutes 48 seconds; GT and RT: 3 minutes 6 seconds; ET and OT: 42 seconds; ET and RT: 48 seconds. When GTs were used, most nurses left the room and returned after a period of time. When using ETs nurses rarely left the room during temperature measurements. Stronge (1980) reported results similar to Takacs and Valenti (1982) in that nurses did not leave GTs in place long enough. De Nosaquo, Kerlan, Knudsen, and Klumpp (1944) distributed a questionnaire to 100 nursing schools in an attempt to determine the minimum time that nurses inserted oral thermometers, and what rationale these times were based on. Of

the 69 replies, 27 left the thermometer in place for less than three minutes, 37 for three minutes, and 5 for longer than three minutes. Reported rationales used for insertion times were based on: manufacturer's suggestion (n = 13), clinical testing (n = 30), common knowledge (n = 26), textbook (n = 26), and experience (n = 10).

Site

The first point to consider in recording accurate temperature measurements is the optimum site for monitoring temperature. Criteria for choosing a particular site include: proximity to major arteries, insulation from external influences, absence of local inflammation and the patient's overall health status (Blainey, 1974). The site should be convenient, harmless and painless, the temperature should not be influenced by local blood flow, and temperature changes at the site should reflect quantitatively and rapidly changes in central temperature (Benzinger, 1969b; Cooper, Cranston, & Snell, 1964). Sites commonly used by nurses to measure temperature are the mouth, axilla, and rectum, with tympanic membrane becoming more common. The relationship between recordings at these sites are constantly under debate, and various authors give different figures. Nursing texts report a $1^{o}F$ ($0.6^{o}C$) difference between oral - axilla and rectal - oral temperatures (DuGas, 1972). Nurses and other health care professionals commonly use this conversion factor in practice when deciding if a patient is "febrile or afebrile". This difference has not been supported by research.

Burton-Fanning and Champion (1903) investigated the relationship of temperature recordings at various sites (mouth, axilla, and rectum). Over 2000

observations were made, using RT as the standard to which other temperatures were compared. Results indicated that RT was 0.4°F greater than OT and 0.9°F greater than AT. Cranston, Gerbrandy, and Snell (1954) and Gerbrandy, Snell, and Cranston (1954) studied convenience samples of 40 and 17 (respectively) healthy individuals and compared oral, esophageal, and rectal temperatures. They used a thermocouple calibrated to ± 0.05°C and recorded the temperature when a steady state was reached. Cranston et al. (1954) reported OTs less than RTs ($\underline{M}$ diff = 0.35 ± 0.01°C); Gerbrandy et al. (1954) supported these results ($\underline{M}$ diff = 0.23°C). Sellars and Yoder (1961), studied nine healthy males over a period of five days. They monitored oral and rectal temperatures simultaneously with a glass thermometer (GT), at three times throughout the day, over three different environmental conditions and following two levels of exercise. They reported that of 1431 pairs of recordings, 15% had a 1°F difference.

Nichols, Ruskin, Glor, and Kelly (1966) attempted to establish an acceptable relationship between oral, axillary, and rectal temperatures but found that individual variations were too pronounced. They studied a convenience sample of 60 healthy individuals, using a glass thermometer (GT), inserted for 12 minutes. The reported findings were: (a) the oral - axillary difference ranged from 0 to 4.2°F; 5% had a 1°F difference, 57% were lower than 1°F and 35% were greater than 1°F; (b) the rectal - oral difference ranged from 0 to 2.8°F, 8% had a difference of 1°F, 67% were less than 1°F, and 22% had a difference greater than 1°F. The assumption that a 1°F difference exists between oral - axillary and oral - rectal temperatures was not supported. Variation in the percentage of a 1°F rectal - oral temperature difference between Sellers and Yoder (1961) and

Nichols et al. (1966) results (15% as compared to 8%, respectively), may be related to the time of insertion: Sellars and Yoder (1961) used an insertion time of three minutes, whereas Nichols et al. (1966) used a 12 minute insertion time. The difference in sample size between the two studies may also have contributed to the difference in results. The evidence suggests that there is no definitive conversion factor for differences in temperatures recorded simultaneously at different sites. It can only be said that in most individuals, rectal recordings are likely to be the highest and skin recordings the lowest.

Oral recordings.

Accuracy of oral temperatures (OTs) is claimed to be superior to rectal or skin temperatures (Cranston et al., 1954; Gerbrandy et al., 1954; Molnar & Read, 1974). Proximity to a large artery (lingual artery) renders the mouth capable of reflecting arterial temperature and thus core temperature fluctuation (Cranston, 1966). Gerbrandy et al. (1954) (N = 7) and Cranston et al. (1954) (N = 40) examined the oral to rectal temperature relationship in healthy individuals as they were heated and cooled. Both studies reported that during heating, OT was quicker to rise than RT and that during cooling, RT remained elevated much longer than OT. They concluded that RT was inferior to OT when monitoring changes occurring at central receptors. Molnar and Read (1974) supported a lag in RT while studying 20 patients undergoing therapeutic hypothermia. These patients had both rectal and esophageal temperatures monitored. RT was the slowest to fall during cooling and rise during rewarming. They suggested that the esophageal or sublingual site is superior to the rectal

site for monitoring changes in temperature.

Laurent (1979) compared oral, axillary, pulmonary artery, and rectal temperatures in 34 acutely ill patients. OT was reported as being lower than pulmonary artery temperature ($\underline{M} = 0.6^{o}C$, $p<.001$): OT was $36.7 \pm 0.7^{o}C$ and pulmonary artery temperature was $37.3 \pm 0.6^{o}C$. These results are supported by Ilsley, Rutten, and Runciman (1983), who compared oral, axillary, pulmonary artery, rectal, and bladder temperatures in five patients. They reported that OT was on average, $0.4^{o}C$ less than pulmonary artery temperature.

Edwards, Belayvin, and Harrison (1978) compared oral, rectal, esophageal, and auditory canal temperatures in twelve healthy volunteers. A basic assumption underlying their investigation was that under experimental conditions, esophageal temperatures provided a reliable index of central blood temperature. Following a control period, RT was greater than esophageal temperature ($0.19^{o}C$, sig), esophageal temperature was greater than OT ($0.06^{o}C$, nonsig) and OT was greater than auditory canal temperature ($0.33^{o}C$, sig). Subjects were then immersed in a hot bath ($41 \pm 0.5^{o}C$). Auditory canal temperature was the first temperature to begin increasing, followed by esophageal, and then OT; RT took the longest to respond. Maximum temperature change was observed from the auditory canal and lowest from the rectum.

Following selection of the oral site, factors in the procedure that may affect accuracy of the recording should be considered, such as: environmental influences, site within the mouth, mouth position (open compared to closed), respiratory rate, oxygen and/or aerosol treatments, tubings within the mouth and length of time of thermometer insertion. Burton-Fanning and Champion (1903)

identified several factors that affect OT: breathing cool air, rapid breathing and cold/heat application to the outside of the cheeks. They also suggested that drinking hot beverages, inhaling cold air, reading aloud, local diseases, sucking lozenges, smoking and capillary dilatation all alter OT. This study is difficult to evaluate as the procedures used to collect data, sample size, and method of analysis are not clearly described.

It is generally believed that oral recordings are more subject to environmental temperature changes than rectal recordings, but this may depend on the methods used. Fox, Fry, Woodward, and Collins (1971) examined oral and rectal temperatures in young men ($N = 12$) exposed to neutral and cold environments. Their results showed little change in RT and a drop in OT when exposed to the cold environment. Based on their results they concluded that OT recordings reflected the cold environment and suggested that RT be taken for the purposes of diagnosing hypothermia. However, OT was recorded for five minutes only, which is two to three minutes less than the time recommended by Nichols and Kucha (1972). Nichols and Kucha (1972) found that the lower the environmental temperature, the longer the subject took to reach a maximum OT recording (environmental temperatures were not as low as those by Fox et al.). Environmental temperatures may affect oral readings in that time required for accurate recording at lower temperatures is prolonged.

Woodham, Parry, and Simms (1967), using GT, studied the effects of drinking ice water and smoking on OT in 74 healthy males; eight were withdrawn due to noncompliance. Subjects were randomly assigned to one of three groups ($n = 22$): iced water, smoking, or control. Oral temperatures were recorded before and

after treatment, which was standardized for all subjects. The control group sat quietly with mouths closed the entire protocol time. A significant difference in OT was found in both the iced water and smoking groups but not in the control group. This study was conducted over several days with an unequal number of subjects being entered each day, which may have had an influence on the results obtained.

Forster, Adler, and Davis (1970) studied effects of drinking iced water on OT in 19 patients: nine afebrile ($\leq 99^{\circ}F$) and ten febrile ($> 99^{\circ}F$). Temperatures were monitored for "15 minutes or more" after ingestion of iced water. A significant drop in OT occurred in all subjects ($\underline{M} = 5.68^{\circ}F$) immediately following the ingestion of the fluid; at the end of the 15 minute period, the OTs were no longer significantly different from baseline. Terndrup, Allegra, and Kealy (1989) reported similar results. They studied 22 healthy volunteers to determine the influence of iced water, hot water, and smoking on OT, RT, and TMT over time. They demonstrated a maximum OT change post ingestion of iced water ($\underline{M}$ diff = $-1.2 \pm 0.2^{\circ}C$, sig) and hot water ($\underline{M}$ diff = $0.9 \pm 0.1^{\circ}C$, sig) at 1.5 minutes. OT was not significantly different from baseline at five minutes post ingestion of iced water and at seven minutes post ingestion of hot water. Smoking was reported as having no affect on OT.

During recording, it is suggested that the mouth be kept closed and position of the thermometer maintained in the posterior pocket of mucus membrane below the tongue. Erickson (1976) studied affects of three different sublingual sites on OT in 50 febrile adults. Using an electronic thermometer (ET), temperature in the right and left posterior and anterior sublingual pockets were

compared. There was a significant difference between posterior and anterior pockets, but no significant difference between right and left posterior pockets. These results are similar to those by Beck and Campbell (1975). In 1980, Erickson again studied the temperature difference between the right and left posterior and anterior sublingual pockets using both an ET and a GT. As well as sites, two methods were compared: slow slide and direct placement. Findings revealed that the posterior temperature was significantly different from the anterior temperature when using the ET; this difference was not found when using the GT. Using the slow slide method as compared with direct placement, there was a significant difference in the temperature recorded ($\underline{M}$ = 0.1°F higher) and the speed at which it was recorded ($\underline{M}$ = 2.23 seconds faster).

Erickson (1976) also tested for the effects of mouth position (open compared with closed) on temperature; the difference, - 0.7 to 1.0°F, was found to be significant, however, clinical importance of this difference was questioned. The difference may have been due to lack of stabilization after the mouth was open and the short time utilized for measuring temperature using the ET. Cooper and Abrams (1984) assessed accuracy of OT in 11 females with mouths open compared to mouths closed, using an ET. After five minutes of mouth open, there was a significant difference in OTs recorded from the anterior pocket ($p<.05$) but not from the posterior pocket ($p>.05$). The nonsignificant difference in the posterior pocket may have been due to the small sample size, or how wide the mouth was open.

Several authors recommend that RT, and not OT, be taken in hyperventilating patients. Tandberg and Sklar (1983) studied 310 subjects admitted to the

emergency department to determine if mouth breathing decreased OT when compared to RT. The subjects were divided into two groups according to respiratory rate (RR): RR $\leq$ 20 , $\underline{n}$ = 118 and RR > 20, $\underline{n}$ = 192. They found a significant difference ($p<.001$) in the rectal - oral temperature difference between patients with an increased RR ($\underline{M}$ diff = 0.93 $\pm$ 0.05^{o}C) and patients with a RR $\leq$ 20 ($\underline{M}$ diff = 0.53 $\pm$ 0.04^{o}C), and it was recommended that patients with RR > 20, have their temperature taken rectally. These results were supported by Durham, Swanson, and Paulford (1986) who studied the oral - rectal temperature difference in 53 critically ill patients (RR $\leq$20/min, $\underline{n}$ = 20 and RR > 20/min, $\underline{n}$ = 33). The rectal - oral differences were 0.69 $\pm$ 0.13^{o}F (RR $\leq$ 20) and 1.30 $\pm$ 0.14^{o}F (RR > 20); a significant difference was found between the two groups ($p<.01$).

Results of a more recent study by Kresovich-Wendler, Levitt, and Yearly (1989) questioned the former results. They studied 366 patients in emergency; Group I consisted of 327 patients defined as being afebrile by both oral and rectal temperature measurements ($\underline{M}$ = 98.1 $\pm$ 1.7^{o}F and $\underline{M}$ = 99.4 $\pm$ 1.1^{o}F, respectively), and Group II consisted of 39 patients defined as afebrile with OT and febrile with RT ($\underline{M}$ = 98.6 $\pm$ 1.2^{o}F and $\underline{M}$ = 102.5 $\pm$ 0.70^{o}F, respectively). Using univariate analysis (t-tests and χ^2), they reported a significant difference ($p<.01$) between Group I and II based on mouth breathing, respiratory rate, supplemental oxygen, oxygen by mask, and heart rate. With further multivariate analysis (backwards elimination stepwise regression model), only heart rate and mouth breathing remained significant in explaining the variance between the two groups. They suggest that respiratory rate, supplemental oxygen

and oxygen by mask only achieved significance due to their association with mouth breathing. This study is limited by a small sample size (n = 39) for multivariate analysis. It is further limited in that they did not control for thermometer placement within the mouth. There is no data reported on reliability and validity testing of the thermometers.

Oxygen and aerosol treatment have been regarded as contraindications to monitoring OT. In a study done by Hasler and Cohen (1982) on 40 afebrile ($<100^{o}F$) healthy subjects, OT during oxygen administration was no different than OT without oxygen delivery. Using a counterbalanced design, subjects who received oxygen by nasal cannula, oxygen masks and venturi masks, were monitored with temperatures taken before, during and following each treatment period. The difference before and after treatment was less than $0.09^{o}F$ when oxygen masks and prongs were used, and was nonsignificant. When venturi masks were used, the before/after difference (M = $0.14^{o}F$) was significant. They concluded that OT was not affected by simultaneous administration of oxygen by mask or nasal cannula; they did not address the use of venturi masks. A similar study by Lim-Levy (1982) on 100 subjects receiving oxygen (nasal prongs at 2, 4, and 6 L/min) found no significant change in OT with oxygen administration, confirming results of Hasler and Cohen (1982).

Kintzel (1966) studied OT and RT in two groups (n = 20) of patients receiving oxygen by high humidity tent and deep nasal catheter. Four readings were done over a two day period. The majority of subjects had oral - rectal temperature differences ranging between 1.0^{o} and $1.4^{o}F$, with 20 to 40% being greater than 1.0^{o} to $1.4^{o}F$.

Dressler, Smejkal, and Ruffolo (1983) examined the question one step further. They compared the difference in OT and RT in 30 men following open heart surgery, all of whom were receiving oxygen via masks. Using an ET, a significant difference was found between OT and RT ($\underline{M}$ diff = 1.46°F). The clinical importance of 1.46°F was questioned and the conclusion was that both RT and OT were accurate temperature assessments when oxygen therapy was being administered but that RT was slightly more stable.

In 1974, Graas compared OT and RT in nine healthy females before and after oxygen administration. Oral - rectal temperature difference was slightly lower following oxygen administration, but the difference was nonsignificant. In view of the results, the routine of taking RT on patients receiving oxygen was challenged. The results may have been due to the small sample size or type of thermometer used. Graas used GTs which were not tested for reliability prior to the study, and as well, used a different thermometer for rectal and oral temperatures.

In 1982, Yonkman examined the effect of cool and heated aerosol treatment on OT. Thirty healthy females had OTs taken prior to treatment, with the mask on, and at one and five minute intervals after the mask was removed. The results indicated that by five minutes post-treatment, the temperature difference had returned to within 0.2°F of baseline, both in heated and cool aerosol treatment. The difference between baseline and treatment was significant ($p<.05$). Yonkman (1982) concluded by stating that this difference, although significant, might not be clinically important.

Nasogastric (NG) and endotracheal tubes are also believed to alter OT and

render it inaccurate. Heinz (1985) examined the difference in oral and rectal temperatures on 20 patients with and without NGs. Using an ET, oral and rectal temperatures were taken with the NG in and then following the NG removal. Heinz (1985) found no significant difference in OT with the NG in or out, as compared to RT ($p>.05$). The results may be inaccurate due to: sample size, the use of two separate thermometers (both were tested before and after but no information is reported on the reliability), and the length of time between temperature readings, which ranged from one to six days.

Three studies examining OTs in intubated patients have been reported in the literature. Ozuna (1976, 1978) compared OTs taken preoperatively and intraoperatively with esophageal temperatures on ten patients undergoing abdominal surgery. OT paralleled esophageal temperature, but was lower in seven subjects. Ozuna (1976, 1978) concluded that OT was a reliable indication of deep body temperature during anesthesia and surgery. Oral probe placement was done blindly during surgery which raises questions on the reliability and validity of the OTs, however due to the close tracking of the OTs with the esophageal temperatures, this does not appear to be a major concern.

Laurent (1979) compared oral, axillary, rectal, and pulmonary artery temperatures in 34 patients who were acutely ill. OT was reported as being $0.6^{o}C$ below the temperature registered in the pulmonary artery. An analysis of variance found no significant difference in temperatures recorded from the mouth and pulmonary artery, based on the respiratory treatment that the patients were receiving. Eleven patients were nasally intubated, five orally intubated. It is possible that any affects on the OT by an endotracheal tube, especially oral,

may be obscured due to the small group of patients examined. In 1984, Cashion and Cason compared the accuracy of OT with RT in intubated patients. Using a repeated measures design Cashion and Cason (1984), demonstrated no difference between RT and OT when comparing pre-intubation temperatures to temperatures taken while subjects were intubated. Cashion and Cason sampled 17 patients undergoing therapeutic hypothermia for coronary artery by-pass grafting. Only 15 patients who completed the study were included in the analysis. The small sample size is a major limitation of this study. It is further limited by lack of control over the order in which temperatures were taken.

The final factor identified as influencing OT recordings is the length of time of thermometer insertion. The duration of recording time is crucial for accuracy. There is no value in making the gesture of placing the thermometer in position for an unspecified and variable length of time. Researchers unanimously agree that temperature results are highly individual, and that ideally each person should have thermometers in place until the reading stabilizes. However, this suggestion lacks practicality. Nichols and colleagues have carried out a series of six investigations of temperature recording and time on 480 subjects. Results indicate that using a GT, the following times should be utilized for oral temperatures: eight minutes for men and nine minutes for women in room temperatures of 65 to 75^{o}F; and seven minutes for all adults in room temperatures of 76 to 86^{o}F (Nichols, Ruskin, Glor, & Kelly, 1966; Nichols & Verhonick, 1967; Nichols & Verhonick, 1968; Nichols, Fielding, McKevitt, & Posner, 1969; Nichols, Kulvi, Life, & Christ, 1972; Nichols 1972a, 1972b; Nichols & Kucha, 1972). These times are described as

optimum placement times, or the time required by 90% of subjects' thermometers to reach optimum temperatures (maximum temperature minus 0.2°F).

Most nursing texts advise three to five minutes for thermometer insertion time for OT, and this is currently being practiced. This advice must be viewed with caution since there is conflicting evidence regarding optimal insertion time for obtaining accurate OTs. Nichols and Verhonick (1968) have shown that only 13% of their subjects reached maximum recordings after three minutes, illustrating the high degree of inaccuracy inherent in practice suggested in nursing texts. Wilkinson, McGinn and Tregilgas (1971) measured the OTs of 15 nursing students for four minutes, recording results every minute; the differences in temperature measurements are not reported. They concluded that the minimum time to ensure accurate OT readings was four minutes. These results are in conflict with those of Nichols and colleagues and could be due to the small sample size and discontinuance of monitoring at four minutes. These two contrasting studies cited provide examples of the importance of research in relation to traditional nursing practices.

Axillary recordings.

Axillary temperatures (ATs) are rarely used in the ICU, due to the belief that of all available monitoring sites, the axilla is the least accurate in reflecting core temperature. Research has indicated that ATs are generally lower than all other measures of deep body temperature, and it is commonly thought that AT is 1.0°F lower than OT. Burton-Fanning and Champion (1903) examined the relationship between oral, axilla, and rectal temperatures. AT was reported as being 0.9°C less than RT. They documented that a maximum AT was

reached in fifteen to fifty minutes. Nichols et al. (1966) compared oral, rectal, and axillary temperatures to determine maximum and optimum placement time of the thermometer, and the relationship between recordings at the three sites. In sixty subjects, maximum axillary recordings required one to twelve minutes; 18% reached maximum by five minutes, 68% by ten minutes, and 90% after eleven minutes. Optimum placement time was reported as nine minutes, with the difference between OT and AT ranging from 0.0^{O} to 4.2^{O}F. One individual's AT was identical to their OT and in two subjects the AT was greater than their OT. Only 5% of subjects had a 1.0^{O}F difference between their AT and OT; 57% were less than 1.0^{O}F and 35% were greater than 1.0^{O}F. These comparisons were made on individuals within the normal temperature range and age and sex were not examined as influencing factors.

Laurent (1979) compared axillary, pulmonary artery, oral, and rectal temperatures in 34 acutely ill patients. There was a significant difference ($p<.001$) between AT and pulmonary artery temperature ($\underline{M} = 36.6 \pm 0.8^{O}$C and $\underline{M} = 37.3 \pm 0.6^{O}$C, respectively, $\underline{M}$ diff = 0.7^{O}C). Ilsley, Rutten, and Runciman (1983) confirmed these results in a similar study comparing axillary, pulmonary artery, oral, and rectal temperatures in five patients. They reported AT as being 0.7^{O}C less than pulmonary artery temperature, and 0.2^{O}C less than OT. Cork, Vaughan, and Humphrey (1983) compared AT with TMT in 56 noncardiac surgical patients. AT was significantly lower than TMT ($p<.05$). The AT was 1.5^{O} to 1.9^{O}C less than TMT.

Axillary temperatures are influenced by environmental factors, position, and length of time for thermometer insertion. Abrams, Royston, Humphrey, and Wolf

(1980) studied thermal features of the female axilla in twelve nurses and seven afebrile patients. They discovered that position of the thermometer probe in the axilla influenced temperature recordings. Accordingly, they suggested that proper probe positioning should be between 2.5 and 4.5 centimeters from the anterior margin of the axilla, along the axilla fold. Although positioning is important, Abrams et al. (1980) stated that the thermal state of the axilla prior to thermometer insertion is a more important determinant of the temperature recorded. Exposure of the axilla to the environment results in the axilla temperature reflecting the environmental temperature. It becomes essential that when taking axilla temperatures, patients must be able to hold their arm close against their chest during the measurements in order to minimize environmental influences.

Rectal recordings.

Rectal temperature (RT) monitoring has long occupied an almost sacrosanct position. Of all the readily available measures, this is the one which above all others has been regarded as an accurate indication of core temperature (Grayson, 1951). For experimental purposes, the rectum has been the traditional site for temperature measurement, since it is generally higher than the others and insulated from external temperature changes (Cranston, 1966). RT is believed to be more stable in variable environmental conditions than skin recordings, but is thought to be slow to reflect accurately changing core temperatures (Cranston et al., 1954; Gerbrandy et al., 1954). Molnar and Read (1974), in studies carried out during open heart surgery, confirmed the slow response of RT to body temperature changes and suggested that the reason was

related to a slower rate of blood flow to the rectum.

Cooper and Kenyon (1957) examined esophageal, rectal, and aorta temperatures in ten patients undergoing a variety of surgical procedures on the aorta. During cooling the RT fell much more slowly than the esophageal temperature, with the maximum deviation occurring during an esophageal temperature range of 30 to 33°C. The difference between esophageal and RTs ranged from 0.3° to 2.3°C. During rewarming, RT was 0.4°C less than esophageal temperature and was much slower to rise. Eventually the RT exceeded the esophageal and aortic temperatures. Cooper and Kenyon (1957) concluded that esophageal temperatures were more reliable than RTs in monitoring deep body temperature. Roberts (1980) studied esophageal, rectal, and skin temperatures in 26 patients undergoing open heart surgery. Results indicated that the esophagus was the quickest to record a temperature change, and the rectum the slowest. Stupfel and Severinghaus (1956) reported similar results in fifteen patients undergoing hypothermia for surgical procedures. RT was slower to fall than esophageal temperature, with a maximum difference of 1.9 $\pm$ 0.7°C. Similar findings have been reported by Grayson (1951) and Benzinger (1969a).

Kresovich-Wendler et al. (1989) examined 366 patients in emergency to determine if predictive criteria existed to identify patients who are febrile by RT and afebrile by OT. A secondary purpose of their research was to determine if a positive correlation existed between oral and rectal temperatures. The correlation coefficient between the oral and rectal temperatures was reported as r = .20. Laurent (1979) compared RT with pulmonary artery temperature and found a statistically significant difference ($\underline{M}$ = 37.5 $\pm$ 0.7°C and $\underline{M}$ = 37.3 $\pm$ 0.6°C,

respectively, $\underline{M}$ diff = 0.2°C). Terndrup et al. (1989) compared RT and TMT in 100 patients: 51 male and 49 female with an average age of 26.5 years (range = 1 month to 85 years). There was no difference between the temperature recorded at the two sites; RT: $\underline{M} = 38.1 \pm 1.1$°C, TMT: $\underline{M} = 38.3 \pm 1.0$°C. The correlation between the two temperature measurements was r = .90. In terms of human dignity and psychological trauma, RTs are much less acceptable than OTs. RTs are highly invasive and personal. Accurate and safe RT monitoring involve several issues: recording time, body position, and angle and depth of thermometer insertion and hazards. Length of thermometer insertion time for RT measurements has been studied by Nichols and colleagues on adults and children (Nichols & Glor, 1968; Nichols, Kucha, & Mahoney, 1972). Nichols carried out five investigations involving rectal thermometer placement times on 307 men, 96 women and 40 children. Final recommendations, summarized in Nichols (1972a), are two minutes for adults in environmental temperatures of 72°F, three minutes for adults in temperatures less than 72°F, and four minutes for febrile children in temperatures of 70 to 82°F.

Kleitman and Doktorsky (1933) studied the effect of body position and sleep on RT. RT fell after standing and a change in position from vertical to horizontal led to a decrease in RT. However, they studied only four healthy men, which greatly limits the generalizability as well as questions any significant findings. Burton-Fanning and Champion (1903) reported similar results form eight healthy subjects. Comparing repeated measures, it was documented that in six of eight subjects the RT increased when the subject moved from a lying to a standing position.

RT is believed to be unaffected by environmental influences and technically straightforvard. Mead and Bonnarito (1949), in an attempt to study the temperature gradient at different points in the rectum, found that it was almost impossible to position probes in exactly the same spot, as evidenced by x-ray. They did find a temperature difference, in that the further into the rectum, the lover the recorded temperature. As well, if feces or sclerosed hemorrhoids were present, the temperature was deemed inaccurate.

Benedict and Slack (1911) and Karlberg (1949) both reported research results that indicated a change in temperature measurement relating to the depth at which the thermometer was inserted. Quiss (1973) studied rectal thermometer positioning and its relation to temperature recording in 49 subjects. Positions that were examined were anterior, posterior, one and one-half inches and three inches. Results indicated that a higher temperature was recorded when the thermometer was inserted three inches, but anterior/posterior did not appear to influence the results.

The majority of nursing texts recommend that rectal thermometers be inserted one to two inches. Nichols (1972b) used one and one half inches insertion in her studies. One and one half to two inches seems sufficient to reach the rectum. Length and angle of insertion are particularly of importance in neonates, in whom anatomical proportions render this procedure hazardous. Several reports exist on the perforation of the rectum with rectal thermometers, with a mortality rate of up to 70% (Smiddy & Benson, 1969; Greenbaum et al., 1969; Merenstein, 1970). These authors recommend not taking RT in an othervise healthy normal baby. Although these reports involve neonates, the potential for

perforating the rectum in adults exists.

Other hazards reported in the literature are the problems of broken thermometers and mercury poisoning (Herrero, 1973; Mofenson & Greensher, 1973). Broken glass is a legitimate hazard; however, in a ten year retrospective study, Mofenson and Greensher (1973) reported no cases of mercury poisoning due to broken thermometers. Another concern documented regarding RTs is in relation to patients with myocardial infarctions (MI). It is believed by some people that anal stimulation may cause an adverse reflex action of the vagus nerve, causing bradycardia and possibly ventricular standstill (Gruber, 1974). Earnest and Fletcher (1969) studied the effect of digital examination on 86 patients with acute MI and reported no change in cardiac rhythm. Gruber (1974) examined the association between rectal thermometer insertion and the occurrence of significant changes in cardiac rate and rhythm based on ECG tracings. The sample consisted of 19 patients with acute MI. Data was analyzed according to the phases of the procedure: baseline, explanation of procedure, positioning, insertion of thermometer, and removal of thermometer. The results revealed that the cardiac rate did in fact increase, but that it was related to turning, and not to the actual insertion of the thermometer. No ectopic cardiac rhythms were documented on any rhythm strips, indicating no relationship between RT and cardiac arrhythmias. McNeal (1978) replicated these results in a similar study using fifteen patients with myocardial infarctions.

Tympanic membrane recordings.

Since the well known work of Benzinger, Kitzinger, and Pratt (1963) and Benzinger and Taylor (1963), the tympanic membrane temperature (TMT) has been

used extensively as an indicator of the core temperature in thermoregulatory studies in humans and is in its early stages of use in clinical practice. Benzinger and Taylor (1963) argue that the true core temperature should be regarded as that of the hypothalamus, since it is the hypothalamus that is the control center for temperature regulation. However, a direct comparison of hypothalamic and tympanic membrane temperatures has not been done in humans (for practical and ethical reasons).

Benzinger and Taylor (1963) attempted to find a convenient location in man to measure temperatures that were similar to hypothalamic temperatures, and suggested the tympanic membrane. In support of this location, Benzinger and Taylor (1963) measured the temperature of the structures in the cranium which were supplied by the internal carotid artery, in one subject. During simultaneous recordings of these temperatures, as well as that of the tympanic membrane, the subject ingested ice. This resulted in similar temperature alteration on all recorded cranial areas, and the conclusion was that the TMT was reflective of hypothalamic temperature.

Terndrup et al. (1989) studied the influence of iced water, hot water, and smoking on OT, RT, and TMT over time in 22 healthy subjects. Although there were significant differences in OT post ingestion of iced and hot water, TMT was reported to have remained consistent. There is no documentation of the TMT measurements post ingestion of the iced and hot water, only the OT. The difference in results from Benzinger and Taylor (1963) may be due to the difference in sample size; Benzinger and Taylor (1963) only used one subject.

Anatomic studies reveal that the tympanic membrane is supplied by two or

three branches of the external and one branch of the internal carotid artery. The hypothalamus is also supplied by the internal carotid artery. It was therefore assumed that if both structures were receiving the same blood supply, that temperatures should be equivalent. This relationship has been measured in animals and similarities have been reported (Fusco, Hammel, & Hardy, 1961; Hammel, Hardy, & Fusco, 1960; McCook, Peiss, & Randall, 1962).

Randall, Rawson, McCook, and Peiss (1963) studied the relationship of TMT and hypothalamic temperature in six cats. They reported that in a control situation hypothalamic temperature was greater than TMT (1.0° to 3.0°C). They then performed bilateral carotid artery occlusion, while monitoring hypothalamic temperature and TMT. Their results indicated a rise in hypothalamic temperature during occlusion and a drop following release; TMT did not change with the hypothalamic temperature change. They concluded that TMT being an adequate measure of hypothalamic temperature was an invalid assumption. They suggested that the TM in cats is primarily heated by carotid blood, while the hypothalamus is cooled by carotid blood. Baker, Stocking, and Meehan (1972) observed good correspondence between TMT and hypothalamic temperatures during many physiological events in cats and monkeys. However, they reported that an increase in ambient temperature had more of a direct effect on TMT than on hypothalamic temperatures.

Marcus (1973a) demonstrated that heating the head of one subject using radiant lamps, produced changes in ear canal temperatures, but not in esophageal temperatures. In a second study, Marcus (1973b), using one subject, demonstrated changes in auditory canal temperatures when the scalp was cooled

and heated. McCaffrey, McCook, and Wurster (1975) examined the influence of head skin temperature on OT, TMT, and esophageal temperature in five healthy subjects. During localized head and neck heating and cooling, both OT and TMT followed the changes in the cutaneous temperature on the same side of the head, although OT responses were less consistent and not as extensive as those of the TMT; esophageal temperatures remained constant during the applications. It was concluded that OTs and TMTs were susceptible to modification by the local environment of the head. It was further concluded that OTs and TMTs would not represent central blood temperature accurately under conditions in which the head environment is drastically different from the core temperature or when localized regions of heating or cooling are present on the surface of the head.

McCaffrey, Geis, Chung, and Wurster (1975) studied three males over a series of experimentations involving heating and cooling of the head. They concluded that during heating or cooling of local regions of the head, TMT followed changes in skin temperature. Cooper, Cranston, and Snell (1964) examined the influence of blood flowing to the meatus on ear temperature in six healthy individuals. They infused warm saline into one carotid artery, while measuring bilateral auditory canal temperature and OT. Ear temperature and OT on the side of the infusion increased; there was no change on the other side. Cooper et al. (1964) also examined the effect of environmental temperature changes on auditory canal temperatures. Raising or lowering the environmental temperature rapidly by 14^{o}C, had no immediate effect on ear temperature.

Nadel and Horvath (1970) studied the effect of ambient temperature on TMT, RT, and skin temperature, in three healthy subjects. Their results indicated

that TMT was not totally independent of ambient temperatures. They concluded that TMT may possess some characteristics of the periphery, particularly those involving local blood flow and ambient temperature influences. Greenleaf and Castle (1972) reported similar results following an experiment on five healthy males, to determine the affect of environmental temperature on auditory canal, skin, and rectal temperature. They concluded that the auditory canal temperature is affected by environmental temperature. The difference in results between Cooper et al. (1964), Nadel and Horvath (1970), and Greenleaf and Castle (1972), may be due to differences in sample size, length of time subjects were exposed to various environmental temperatures and method of measuring "ear temperature".

Livingstone, Grayson, Firm, Allen, and Limmer (1983) examined the affects of cold exposure on skin, rectal, esophageal, auditory canal, and oral temperatures in five healthy volunteers. They concluded that environmental temperatures may affect auditory canal temperature more rapidly than other deep body temperatures. During control, the auditory canal temperature was 0.2°C higher than esophageal temperature, and 0.4°C higher than OT. During exposure to cold, the esophageal temperature was higher than the auditory canal temperature. Cooper et al. (1964) compared OT with auditory canal temperature measured at four sites, in twenty-one healthy individuals. Temperatures recorded at the various sites within the auditory canal differed, with the innermost being the highest and the outermost being the lowest. The maximum recorded difference between sites was 0.5 to 0.83°C. When comparing the innermost auditory canal temperature with OT, ear temperature was always lower than OT by 0.05 ± 0.18°C.

Gibbons (1967) compared OT with auditory canal temperature in four individuals over four separate trials. Correlation between OT and auditory canal temperatures ranged between r = .85 to r = .99, with a temperature difference at peak OT of 1.16°F. Dickey, Ahlgren, and Stephen (1970) compared TMT, RT, and esophageal temperature in 50 children undergoing surgery. TMT followed esophageal temperatures closely and were rarely more than 0.5°F different from esophageal temperatures. RT is not mentioned in their results. The probe was changed partway through the study, but no mention is made of the reliability and validity of either probe used. Wilson, Knapp, Traber, and Priano (1971) examined temperatures recorded at four sites (two rectal, esophageal, and tympanic membrane) in 54 children during anesthesia. Resulting correlations between the various sites were as follows: rectal - rectal: $r > .80$; tympanic - esophageal: $r > .80$; all other correlations were $r < .80$. Regression analysis revealed a significant difference between esophageal temperature and RT. No statistics or results are available on the actual temperature measurements recorded at the various sites. Terndrup et al. (1989) compared TMT and RT in 100 patients ranging in age from one month to 85 years ($\underline{M} = 26.5$). Average RT was 38.1 $\pm$ 1.1°C and average TMT was 38.3 $\pm$ 1.0°C. The correlation between the two temperatures was $r = .90$ ($p<.001$). It is not reported whether the temperature difference between RT and TMT is significant or non-significant. As well, there is no documentation regarding the procedure of rectal and tympanic temperature monitoring. Dickey et al. (1970), Wilson et al. (1971), and Terndrup et al. (1989) conclude that TMT is considered to be reliable, practical, and clinically useful as a means of monitoring core

temperature. Webb (1973) also studied the relationship between esophageal and tympanic membrane temperatures in 35 patients undergoing cardiopulmonary bypass. Esophageal and tympanic membrane temperatures correlated closely, with esophageal generally being lower than TMT: 55% were $\leq 0.1^{o}C$: 89% were $\leq 0.3^{o}C$, and 94% were $\leq 0.5^{o}C$. The maximum difference between esophageal and tympanic membrane temperatures was $1.0^{o}C$, and this occurred in two out of 421 readings. Singer and Lipton (1975) studied twenty-nine surgical patients and compared their esophageal and tympanic membrane temperatures. They concluded that TMT was greater than esophageal temperature, which is in agreement with Webb (1973). Lombardi-Garner (1985) studied esophageal and tympanic membrane temperatures in thirty patients undergoing abdominal surgery and reported TMTs as being greater than esophageal temperatures.

Cork, Vaughan, and Humphrey (1983) investigated the relationship between tympanic membrane, esophageal, rectal, blood, skin, and nasopharyngeal temperatures in 56 patients undergoing non-cardiac surgery. They reported that TMT, esophageal, and nasopharyngeal temperatures cluster together, and were the most accurate of all sites measured. Due to possible hazards involved in tympanic monitoring, they suggest that esophageal or nasopharyngeal sites should be utilized. Cork et al. (1983) results are similar to those obtained by Davis, Barnes, and Bailey (1981), who measured nasopharyngeal, esophageal, rectal, and auditory canal temperatures in twenty patients undergoing open-heart surgery. Davis et al. (1981) found that auditory canal temperature showed less variability than nasopharyngeal temperature, with respect to esophageal temperature. RT results are not reported.

Shiraki, Konda, and Sagawa (1986) studied temperature monitoring in three individuals undergoing hyperthermia treatment for cancer. They reported esophageal temperature as being similar to pulmonary artery temperature, but greater than aortic blood temperature ($\underline{M}$ diff = 0.12°C), while TMT was less than both pulmonary artery and aortic temperature ($\underline{M}$ diff = 0.2° and 0.8°C, respectively). They concluded that esophageal temperatures more accurately reflected rapid blood temperature changes than TMTs. These conflicting results may be due to the small sample size or the hyperthermia treatment. A later study done by Shinozaki, Deane, and Perkins (1988) on patients undergoing elective coronary artery bypass grafting reported a significant difference between TMTs and RTs. They do not indicate sample size or method of arriving at the significant difference.

Summarizing the studies that have been reviewed, TMT monitoring appears to be practical, reliable, and clinically useful as a means of measuring core temperature. When using this method to monitor temperature it is important that the nurse is cognizant of environmental and local factors that may influence the temperature at this site. However, tympanic membrane temperature monitoring is not without risks, and perforations of the tympanic membrane have been reported. Wallace, Marks, Adkins, and Mahaffey (1974) reported that in more than 100 patients they had seen two cases of tympanic membrane perforation following the use of a tympanic membrane temperature probe. Dickey, Ahlgren, and Stephen (1970) reported oozing from the ear in two of fifty patients following TMT monitoring. As well, Webb (1973) reported that out of 35 subjects, two developed ear blood staining, and one subject developed otitis externa following

use of a TMT probe.

TMT monitoring in the clinical situation appears straight forward, in that the probe is inserted into the ear canal just far enough to maintain a seal. Product information on tympanic membrane thermometers, for clinical use, state that cerumen does not effect the temperature recorded. However, there is no information available regarding substances such as blood. This could present in a practical problem in the ICU where patients are often admitted following trauma, with bleeding/oozing into the ear canal.

Summary and Areas For Further Research

The majority of research studies revieved are limited by use of nonprobability sampling, healthy (rather than ill subjects), small sample sizes, and age restrictions. Of the four monitoring sites revieved, RT is likely to be highest, and AT lowest, but there is no standard conversion factor to differentiate between recordings obtained at various sites. OT monitoring has been documented to be an accurate method of monitoring core temperature. There is evidence to suggest that OT is superior to RT during times of rapid temperature change in patients. One major criticism of OT is the possibility of variability due to environmental influences. Research suggests that length of time to register OT is affected by environmental influences, not the temperature itself. Thermometer site and mouth position have both been implicated in influencing OT recordings. Results reported have indicated that the posterior sublingual pocket is the most reliable position for placement of the thermometer. Using an ET and monitoring temperature in the posterior sublingual pocket, several investigators have reported conflicting results when examining

the effect of mouth position (open compared to closed) on OT (at normal respiratory rates). Several studies on the effects of oxygen (via mask and prongs) and one study on the effect of NG tubes on OT, have reported that neither oxygen or NG tubes significantly effect OT. There is limited research on the accuracy of monitoring OTs in orally intubated critically ill patients. The one study (Cashion & Cason, 1984) that has examined this practice, has concluded that there is no significant difference between oral - rectal temperature difference before or after intubation. Risks involved with OT monitoring are related to broken glass.

RT monitoring, although commonly thought of as the most "accurate" reflection of core temperature, has been reported to be slow to respond to rapid temperature changes, and is therefore inadequate for monitoring during rapid heating and cooling. RT recordings are influenced by the depth of thermometer insertion and changing body position (horizontal to vertical). There has also been some suggestion of environmental temperatures affecting RT. Risks associated with RT monitoring are rectal perforation and laceration from broken thermometers. RTs are also uncomfortable for the patient, both psychologically and physically.

AT is rarely used to monitor temperature in the ICU. AT recordings have been shown to be lower than all other sites monitored. ATs are affected by environmental temperature, and therefore considered to be the least accurate of all available sites. There are no risks involved with monitoring AT.

TMT has been regarded as the most "accurate" measure of core temperature, based on the assumption that it reflects hypothalamic temperature. The basis

for this assumption rests largely on the work done by Benzinger and colleagues, using single subject experiments. Further experiments by other investigators have supported the results of Benzinger's research; however, they have identified both local and environmental factors as influencing TMT. The risks involved with TMT monitoring are perforation of the tympanic membrane and increased risk of infection.

In summary, although temperature monitoring is a nursing task, and has been practiced since the late 1800's, the literature reveals that the procedure has not been widely studied, and there is little known about monitoring OT in orally intubated critically ill patients. The majority of published studies have used small sample sizes, nonprobability sampling, and normal individuals which greatly limits generalizability.

Due to frequent monitoring of temperatures, advocacy of using rectal over oral temperatures in intubated patients, and lack of experimental data, it would be appropriate to examine OT monitoring in intubated critically ill patients. Further research in this area would increase our knowledge and thereby improve the practice of temperature monitoring in orally intubated critically ill patients.

CHAPTER III

STUDY DESIGN AND METHOD

Design

A pre/post experimental design (Campbell & Stanley, 1963), utilizing subjects as their own controls, was used to compare differences in OT, AT, RT, and TMT, of patients in the ICU, with and without an oral endotracheal tube in situ.

Pre/post experimental

O E O

O: temperature measurements

E: extubation

Sample

The minimum number of ICU patients required to determine a significant difference of 0.2°C between OTs measured with and without an oral endotracheal tube in situ, (with a power of 0.80) was calculated to be N = 65 (Cohen, 1969). This calculation was based on a two-tailed test, with a significance level of 0.01. Since there was no documentation in the literature regarding the correlation between OT differences as recorded with and without an oral endotracheal tube in place, r = .80 was estimated (Appendix A).

Subjects

A nonprobability sample of 66 orally intubated patients was selected from patients admitted to an adult ICU between January and August, 1989. The adult ICU from which the patients were selected was a mixed medical - surgical unit. Consenting patients participated in both groups of this study, with and without an endotracheal tube. All patients eligible for entry into the study were to be approached by the investigator. It was understood from the outset that some patients who would be eligible for entry into the study would be missed due to reasons beyond the investigator's control. To describe the patients that were missed, and subsequently identify any selection bias that might have occurred, a list of eligible patients not entered into the study was kept; biographical data and reason for exclusion was documented.

Inclusion Criteria

Patients eligible for entry into the study were in the ICU, orally intubated, and had an order to be extubated on their charts. As well, they had to be able to read and understand English, and sign an informed consent. If a patient was unable to write, but understood the consent, a witness was allowed to sign the consent for the patient. Only patients 17 years of age or older were entered. (The age was set by the age limit of the unit.)

Exclusion Criteria

Patients who had an oral/rectal or bilateral ear/axilla abscess and/or infection were deemed not eligible for the study. Further exclusion criteria included surgical procedures or trauma to the mouth, ears, axilla, or rectum. Patients with rectal anastamosis or sclerosed hemorrhoids were also excluded.

Any patient who was receiving, and/or had received, any of the following treatments within thirty minutes prior to temperature monitoring were excluded: 1) fluid challenge, and/or blood products, 2) local heating/cooling, and 3) medication which causes vasodilation.

Withdrawal Criteria

In situations where the protocol was violated, the patient was to be withdrawn from the study. As well, patients who did not comply with the protocol or who required re-intubation were to be withdrawn from the study. Any patient who asked to be withdrawn from the study was to have their request fulfilled.

Instruments

All axillary, oral, and rectal temperatures were recorded with the same IVAC^{R} electronic thermometer and its accompanying oral and rectal probes; tympanic temperature was measured with the FirstTemp^{R} thermometer, as well as with the Hi-Lo Temp^{R} thermometer continuously. The IVAC^{R} and the Hi-Lo Temp^{R} thermometers were tested for concurrent validity and test-retest reliability, before and every two months during data collection in a well stirred water bath against a total immersion digital platinum resistance laboratory thermometer (Guidline 9540^{R}). Both oral and rectal probes of the IVAC^{R} and four of the Hi-Lo Temp^{R} probes (randomly chosen from the same lot number) were used for testing. To test for concurrent validity, the probes were suspended to the level of the Guidline^{R} probe (approximately three inches), in the water bath and put in the testing mode according to the manufacturer's instructions; IVAC^{R} probes were tested in both monitor mode and steady state. The probes were

checked at five intervals over their entire range (32, 35, 37, 39, and 42°C), against the Guidline® thermometer.

Prior to testing the thermometers in question, the Guidline® thermometer had to be stable to one hundreth of a degree Celsius for a period of ten minutes. Temperatures from each probe being tested were recorded. To assure the accuracy of readings during data collection, the thermometer was to be rechecked using the above procedure if the thermometer indicated a malfunction, or if any probes were replaced during data collection. No malfunctions occurred during the study period, and all continuous probes came from the same lot number.

Procedure

The research was conducted in two phases. Phase I consisted of a pilot study conducted on six patients to determine timing of temperature measurements in relation to the presence of the endotracheal tube; Phase II consisted of the actual data collection (Appendix B). The budget and time line are included in Appendices C and D, respectively.

Phase I (Pilot Study)

During the pilot study, the patient's tympanic membrane temperature was monitored continuously for a minimum of twenty minutes prior to and a minimum of twenty minutes following extubation, to determine if and when a steady state existed in temperature monitored before, during, and following extubation. A steady state was said to exist if the temperature varied no more than $\pm$ 0.2°C, for a five minute period. Attainment of steady state was used to determine the times at which temperature measurements at all four sites (mouth, axilla, rectum, and tympanic membrane) would be monitored.

Results of the pilot study revealed that steady state was attained at zero to nine minutes post insertion of the Hi-Lo Temp^{R} probe. The temperature ranged from - 0.1 to 0.6^{o}C during extubation and remained at steady state post extubation in five patients; the remaining patient took one minute to attain steady state post extubation. Steady state remained for the full twenty minutes of monitoring post extubation in five patients and for seventeen minutes in the sixth patient.

Based on results from the pilot study (see Table 1), the Hi-Lo Temp^{R} probe was to be in place for a minimum of nine minutes prior to recording temperatures from the various sites. If at nine minutes, steady state had been attained, AT, TMT, OT, and RT would be taken; if steady state had not been attained, the temperatures would not be recorded until a steady state was attained. Post extubation, once a steady state was attained, the four temperature measurements were repeated.

Phase II

Prior to extubation, eligible patients in the ICU were approached by the investigator. The study was explained and the consent form reviewed with the patient (Appendix E). Following agreement to participate and signing of the consent form, the Hi-Lo Temp^{R} probe was inserted into the patient's ear canal, opposite to the endotracheal tube, and the ear covered with a four by four gauze. The purpose of the Hi-Lo Temp^{R} probe was to monitor the TMT continuously to determine steady state, and therefore, the point at which to monitor temperatures at all four sites. As well, it was used to provide an indication

Table 1

Time to Reach Steady State Pre and Post Extubation

Subject	Pre (min)	Post (min)
1	2	0
2	9	0
3	0	0
4	4	1
5	0	0
6	9	0

Note. Times do not include the five minutes used to define steady state.

of an actual temperature change during the procedure. Following insertion of the Hi-Lo Temp^{R} probe, the patient was positioned on his/her side, with the monitored ear down, and the head of the bed raised 45 to 90^{o}. This was done to prepare the patient for extubation (head up) while minimizing movement during the procedure (side lying for ease of rectal measurements).

The axillary temperature required a minimum of nine minutes for stabilization (Nichols et al, 1966). Once the patient was positioned and comfortable, the oral probe of the IVAC^{R} thermometer was inserted into the axilla opposite the endotracheal tube, and temperature monitoring initiated (monitor mode). During the stabilization period, the following biographical

data was collected to describe the characteristics of the patients: age, sex, APACHE score (calculated over the 24 hour period prior to the study) and primary indication for admission to ICU. The APACHE score is a severity of illness classification tool developed for and used with critically ill patients (Knuase, Draper, Wagner, & Zimmerman, 1985).

It has been suggested that NG tubes, dental status, respiratory rate, and oxygenation influence OTs. Therefore information on these factors was documented. The temperature of the ventilatory humidification was recorded. Mouth position was monitored; if there was a visible space between the lips, the mouth was categorized as "open" and if the lips were together, it was "closed". Mouth position was monitored for a five minute period immediately preceding and during OT recording.

Once steady state had been attained, and a minimum of nine minutes had passed, the patient's axillary, tympanic membrane, oral, and rectal temperatures were taken. The investigator and a trained research assistant carried out the protocol. On most occasions the investigator inserted the probes and a research assistant recorded the temperature. (There were occasions when only the investigator or research assistant were available; on those occasions, the person available performed both.) The patient was then extubated, and the temperatures repeated (following a minimum stabilization period of nine minutes for the AT) (see Figure 2). The order in which the temperatures were taken (AT, TMT, OT, and RT) was based on the time required for registering the temperature at each of the sites, with the goal of minimizing the time span between all of

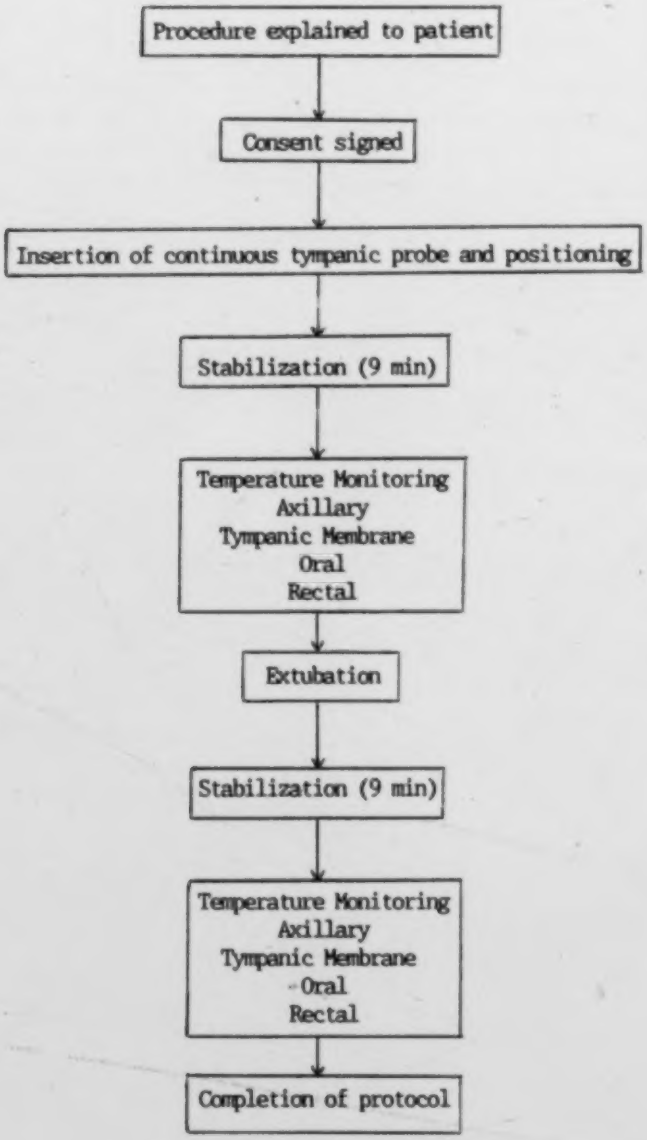

Figure 2. Protocol procedure.

the four temperature recordings. (By minimizing the time span between all four temperatures, the influence of an actual temperature change would also be minimized.)

Each temperature monitored at the various sites required a stabilization period prior to the temperature being recorded. The FirstTemp^{R} thermometer indicated, by an audible tone, that measurement was complete; all remaining temperatures were required to remain constant for one minute prior to the temperature being recorded. Stabilization periods were timed using the same independent time piece. During the entire protocol, the patient was required to stay in the position of placement. The patient was discouraged from talking and was not disturbed by health care workers (i.e. assessment, physical treatment, chest x-ray) and/or family. Patients were not allowed to have anything by mouth from the beginning of the first stabilization period until completion of the protocol.

Data Analysis

Descriptive statistics were determined for all data collected: age, sex, APACHE, respiratory rate, primary indication for admission to the ICU, and all temperature measurements. A t-test for paired samples ($\alpha = .01$, two-tailed) was done to estimate if a significant difference existed between OT measurements recorded with and without an oral endotracheal tube in situ. Further analysis for differences in temperature according to site (AT, TMT, and RT), with and without an oral endotracheal tube in situ, were done with t-tests for paired samples ($\alpha = .01$, two-tailed). Pearson correlations were done to determine if a positive relationship existed between the temperatures recorded at all four

sites. There was one instance of a missing TMT temperature measurement due to low battery. In this case the mean value for that variable was substituted.

Although the study was not designed to examine the affect of other variables on OT measurement, analysis was done to examine the affect of teeth, mouth position, nasogastric tube, and respiratory rate on OT using t-tests ($\alpha = .01$, two-tailed). An analysis of variance with Scheffe's test ($\alpha = .05$) was used to determine if room temperature or the temperature within the endotracheal tube had an affect on the OT. A chi-square test ($\alpha = .01$) was used to determine if there was a significant difference in sex and primary reason for admission to the ICU between those patients entered and not entered into the study; t-tests ($\alpha = .01$, two-tailed) were used to determine if the two groups were statistically different based on age, APS, and APACHE. The validity and reliability of the instruments was estimated using t-tests for paired samples ($\alpha = .01$, two-tailed).

Ethical Considerations

Ethical guidelines of the University of Alberta, the CNA (1983), and those of the institution were followed. Subsequent to ethical approval from the Faculty of Nursing and the institution, and prior to the pilot study, the investigator explained the study and its relevance to the general nursing staff of the Adult ICU, and responded to any questions or concerns regarding the protocol.

Participation in the study was voluntary. The investigator met with each patient (or family member) and explained the nature of the project. If there was agreement to participate, a signed, witnessed written informed consent was

obtained. Confidentiality and anonymity was maintained. It was made clear that participation was voluntary and the patient could withdraw at any time without penalty. In no situation was the study protocol allowed to interfere with delivery of patient care.

CHAPTER IV

RESULTS

To determine if there was a difference in OT measured with and without an oral endotracheal tube in situ, the data from 65 orally intubated patients in ICU were analyzed. Sixty-six patients were actually entered into the protocol; there was one withdrawal from the study due to the need for re-intubation. This patient was not included in the final data analysis. It was anticipated that patient enrollment would be completed in a much shorter time period. Two major obstacles that delayed the enrollment were attempts to obtain informed consent from patients in the ICU, and lack of notification of patients that were ready for extubation.

Validity and Reliability of Instruments

Prior to and every two months during data collection, IVAC^{R} and Hi-Lo Temp^{R} thermometers were checked to establish concurrent validity and test-retest reliability. Rectal and oral probes of the IVAC^{R} were tested, in both monitor mode and steady state, and four probes from the same lot number of the Hi-Lo Temp^{R} thermometer were tested as outlined in the procedure. When testing the oral and rectal probes of the IVAC^{R} in monitor mode, at 32^{o}C, the thermometer failed to display a recording. The reason for this cannot be explained. This would have been a concern if the temperature measurements obtained from patients would have been below 35^{o}C; however, no temperatures below 35^{o}C were recorded.

A paired t-test ($\alpha = 0.01$, two-tailed) between each probe and the standard was conducted at each temperature level, for all four times that the thermometers were checked (see Table 2). A significant difference ($p<.01$) was

Table 2

Temperatures Measured by Standard and Study Thermometers

	Temperature (in ^{o}C)				
Probe	32	35	37	39	42
Standard	32.17±.17	35.37±.24	37.20±.09	39.04±.10	41.54±.38
HI-LO^{R}					
1	32.08±.15	35.20±.28	37.08±.10	38.90±.18	41.38±.47
2	32.05±.13	35.20±.28	37.03±.06	38.83±.15	41.37±.51
3	32.05±.13	35.23±.26	37.05±.06	38.93±.15	41.40±.42
4	32.05±.13	35.20±.22	37.05±.06	38.93±.15	41.38±.47
IVAC^{R}					
Rectal^{a}	32.65±.17	35.78±.25	37.63±.05	39.40±.14	41.95±.29
Rectal^{b}	—	35.30±.10	37.23±.13	39.10±.14	41.58±.37
Oral^{a}	32.63±.15	35.78±.25	37.63±.05	39.48±.15	41.93±.33
Oral^{b}	—	35.30±.10	37.25±.10	39.08±.13	41.58±.37

Note. All temperatures are reported as M ± SD.

a = steady state.

b = monitor mode.

found between the standard and the IVAC^{R} rectal and oral probes when tested in steady state at all five temperatures checked, on each occasion tested. Two of the Hi-Lo Temp^{R} probes (M_3 and M_4) were significantly different ($p<.01$) from the standard at 35 and 37^{o} C only. The differences from the standard for each probe are listed in Table 3.

Due to the significant difference between IVAC^{R} rectal and oral probes tested in steady state and the standard, it was decided that all temperature measurements made with the IVAC^{R} thermometer would be made with the thermometer in monitor mode. Based on the remaining results, it was concluded that the thermometers (IVAC^{R} and Hi-Lo Temp^{R}) demonstrated both concurrent validity and test-retest reliability.

Patient Characteristics

From January to August 1989, a total of 225 critically ill patients in the ICU were assessed as eligible for entry into the study. Sixty-six patients were entered and 159 patients not entered into the study. Of the patients not entered into the study, the two major explanations were that 1) the investigator was not notified (88/159), and 2) it was impossible to obtain an informed consent due to the patient's condition and absence of family members (36/159). A description of the reasons that patients were not entered into the study as well as their primary reason for admission to the ICU is found in Table 4. There was no information collected on patients who were admitted to the ICU and who subsequently had a tracheostomy performed, were transferred to another institution, or who died.

Table 3

Differences Between Standard (S) and Study Thermometers

	Temperature (in °C)				
Probes	32	35	37	39	42
Hi-Lo^{R}					
S - 1	.10±.04	.17±.08	.12±.07	.14±.15	.17±.15
S - 2	.12±.06	.17±.08	.15±.06	.18±.14	.17±.11
S - 3	.12±.06	.15±.04*	.15±.05*	.11±.10	.14±.11
S - 4	.12±.06	.17±.02*	.15±.05*	.11±.10	.17±.15
IVAC^{R}					
S - R^{a}	-.48±.03*	-.40±.03*	-.43±.07*	-.37±.04*	-.41±.10*
S - R^{b}	—	-.03±.03	-.03±.07	-.07±.04	-.03±.02
S - 0^{a}	-.45±.03*	-.40±.03*	-.43±.07*	-.44±.07*	-.38±.07*
S - 0^{b}	—	-.03±.03	-.05±.08	-.04±.04	-.03±.02

Note. IVAC^{R}: R = rectal probe, 0 = oral probe.

a = steady state.

b = monitor mode.

* $p < .01$.

Table 4

Reasons Patients Not Entered Categorized by Primary Reason for Admission

Reason not Entered	Primary Reason for Admission				
	Respiratory	Neurological	Cardiovascular	Other	Total
No Consent	22	6	5	3	36
Refused	17	0	6	0	23
Not Notified	41	17	22	8	88
Exclusion	4	6	1	1	12
Total	84	29	34	12	159

One patient was entered and withdrawn from the study due to a need for re-intubation. The patient was a 46 year old female, admitted to the ICU with respiratory problems. The patient was withdrawn prior to the extubated temperature measurements being recorded. Her biographical data was subsequently grouped and analyzed with the data of patients not entered into the study.

Patients not entered into the study were no different from patients entered in terms of age, sex, and APS. There was a significant difference ($p<.01$) between the two groups based on the primary reason for admission to the ICU (see Table 5). Differences between the total APACHE score did not reach significance, but indicated a trend towards the score being higher in patients not entered.

Table 5

Patient Characteristics

Characteristic	Group	
	Entered (n=65)	Not Entered (n=160)
Age	61±17[a]	55±21[a]
APS	11.4±5.6[a]	12.5±6.2[a]
APACHE	19.5±9.3[a]	15.8±7.1[a]
Sex		
Male	48 (73.8%)	94 (58.8%)
Female	17 (26.2%)	66 (41.3%)
1[y] Reason for admission		
Respiratory	35 (53.8%)	85 (53.1%)
Neurological	3 (4.6%)*	29 (18.1%)*
Cardiovascular	26 (40%)*	34 (21.3%)*
Other	1 (1.5%)	12 (7.5%)

a = Mean ± SD.

*$p<.01$, χ^2.

Sixty-five patients were entered into and completed this protocol; 17 were female and 48 were male. (This female/male ratio is consistent with the female/male ratio within the ICU.) The age of the patients ranged from 17 to 96 years ($\underline{M}$ = 61 $\pm$ 17). Primary reason for admission to the ICU in order of greatest occurrence was respiratory (35), cardiovascular (26), neurological (3), and hematological (1). The severity of illness indicator (APACHE) ranged from 9 to 36 ($\underline{M}$ = 19.5 $\pm$ 9.3). The APS (acute physiological score) portion of this score ranged from 2 to 32 ($\underline{M}$ = 11.4 $\pm$ 5.6).

Mode of ventilation during the temperatures taken with the endotracheal tube in situ was spontaneous, T-piece or CPAP for 28 patients, pressure support for 12, synchronized intermittent mechanical ventilation for 22, and assist control for three patients; inspired oxygen content ranged from 30 to 55 percent. Once extubated, 59 patients were placed on oxygen via nasal prongs and six on a mask system, with the oxygen ranging from two to ten liters/minute.

The temperature (measured with the Hi-Lo Temp^{R}) during the act of extubation ranged from 37.0 $\pm$ 0.7^{o}C to 37.2 $\pm$ 0.7^{o}C. The Hi-Lo Temp^{R} indicated that the patient's temperature increased over the protocol period, from 36.99 $\pm$ 0.68^{o}C at the outset to 37.18 $\pm$ 0.66^{o}C at the completion of the protocol ($\underline{M}$ diff = - 0.19, $p<.01$). Room temperature was monitored during each procedure and ranged from 22.2 to 26.7^{o}C ($\underline{M}$ = 24.6 $\pm$ 1.0^{o}C).

Temperature Measurements With and Without an Endotracheal Tube

Temperatures obtained with and without an endotracheal tube in situ from the various sites are shown in Table 6. A paired t-test (α = 0.01; two-tailed) indicated a significant difference ($p<.01$) between both AT and OT measured with

and without an endotracheal tube in situ. Further paired t-tests ($\alpha = 0.01$, two-tailed) revealed that TMT and RT recorded on patients with an endotracheal tube were not significantly different from temperatures recorded on patients without an endotracheal tube. Results suggest a warming effect in the axillary and tympanic membrane temperatures from before to after the endotracheal tube was removed, whereas the oral and rectal temperatures suggest a cooling trend (see Table 6).

Table 6

Temperature Measurements According to Site, With and Without an Endotracheal Tube

	With		Without		
Site	M±SD	Range	M±SD	Range	M diff±SD
Axilla	37.28±.69	35.4-38.9	37.40±.67	35.4-38.9	-.12±.25*
Tympanic	37.37±.65	36.0-39.2	37.41±.67	35.9-39.0	-.04±.03
Oral	37.59±.57	36.1-38.9	37.51±.57	36.0-38.9	.08±.20*
Rectal	37.87±.60	36.2-39.3	37.85±.62	36.2-39.4	.03±.21

Note. All temperatures are recorded in degrees Celsius.

*$p < .01$.

The range of differences in temperatures between site as measured without the endotracheal tube, are listed in Table 7. The maximum temperature range occurred between the axillary and tympanic membrane temperatures (2.2°C). Temperature differences from axillary to oral and tympanic to oral displayed the smallest range, 1.5°C. Tympanic to rectal and oral to rectal range was 1.6°C, with the axillary to rectal being 1.8°C. A positive correlation was found between temperatures measured at all four sites, without the endotracheal tube in situ. Correlations ranged from r = .84 (axilla - tympanic) to r = .92 (oral - rectal) (see Table 8).

Table 7

Range in Temperature Differences Recorded at Various Sites (Without Endotracheal Tube)

Site	Temperature Range (°C)
Axilla - Tympanic	- 1.1 to 1.1
Axilla - Oral	- 1.0 to 0.5
Axilla - Rectal	- 1.4 to 0.4
Tympanic - Oral	- 1.0 to 0.5
Tympanic - Rectal	- 1.4 to 0.2
Oral - Rectal	- 0.9 to 0.7

Table 8

Correlations Between Temperatures Recorded at all Four Sites (Without Endotracheal Tube)

Site	r
Axilla-Tympanic	.84
Axilla-Oral	.90
Axilla-Rectal	.89
Tympanic-Oral	.88
Tympanic-Rectal	.88
Oral-Rectal	.92

Factors which may Influence Oral Temperature

The following factors were examined in relation to OT measurements: teeth, mouth position, nasogastric tube, temperature within the endotracheal tube, and room temperature. T-tests and analysis of variance were used to evaluate the effect of each. The present study was not designed to examine these factors and their affect on OT, however, in an attempt to extract as much information as possible, the data was analyzed beyond the main hypotheses. The following results should be viewed with caution.

Teeth

Twenty-eight patients were edentulous for the entire procedure, while 37 had

their teeth in situ. To determine if the presence/absence of teeth had an affect on OT, t-tests for independent groups ($\alpha = .01$, two tailed) were applied to the OTs of patients with and without teeth while the endotracheal tube was in situ, and to the OTs of patients with and without teeth once the endotracheal tube was removed. Analysis showed no significant difference between the OTs of patients with or without teeth as measured when the endotracheal tube was in. As well, there was no significant difference between the OTs of patients with or without teeth, as measured when the endotracheal tube was removed (see Table 9).

Table 9

Oral Temperature Differences Between Patients With and Without Teeth

	With Teeth[a]	Without Teeth[b]
Group	M ± SD	M ± SD
With endotracheal tube	37.55±.60	37.65±.54
Without endotracheal tube	37.48±.61	37.55±.53

$a_{\underline{n}} = 37$

$b_{\underline{n}} = 28$

Mouth position

To determine if mouth position (open versus closed) had an affect on the OT, mouth position was monitored five minutes prior to, and during the OT measurements. While intubated, 26 patients had their mouth open, 39 had their

mouth closed, as compared to 34 open and 31 closed while extubated. T-tests for independent groups ($\alpha = .01$, two-tailed) were applied to the OTs of patients with mouth open versus mouth closed, while intubated and to the OTs of patients with mouth open versus mouth closed once extubated. The analysis revealed no significant difference between the OTs of patients with mouth open versus mouth closed with an endotracheal tube and no difference between the OTs of patients with mouth open versus mouth closed without an endotracheal tube (see Table 10).

Table 10

Oral Temperature Differences Between Patients With Mouth Open and Closed

	Mouth open		Mouth closed	
Group	M ± SD	n	M ± SD	n
With endotracheal tube	37.50±.54	26	37.66±.59	39
Without endotracheal tube	37.51±.60	34	37.51±.55	31

Nasogastric tube

Fifty-seven patients had a nasogastric tube in situ during the entire procedure while eight did not. The small number of patients who did not have a NG tube precluded statistical analysis of the affects of a NG tube on OT.

Respiratory rate

Respiratory rate of patients with an endotracheal tube ranged from 8 to 34

($\underline{M}$ = 18 $\pm$ 6) and without an endotracheal tube, they ranged from 12 to 36 ($\underline{M}$ = 21 $\pm$ 6). When examining the affect of respiratory rate on OT, only the OT recorded without an endotracheal tube, was considered. (It was assumed that an increase in respiratory rate with an endotracheal tube in situ would not affect the OT, since the gases would be moving through the tube and not in direct contact with the oral tissues.) The respiratory rate was divided into two groups, $\leq$ 20 ($\underline{n}$ = 36) and > 20 ($\underline{n}$= 29). (Respiratory groups were chosen based on previous groupings reported in the literature.) A t-test for independent groups (α = .01, two-tailed) indicated no significant difference between the two groups, in the OT recorded without an endotracheal tube.

Temperature within the endotracheal tube

Temperature of gases within the endotracheal tube was monitored and ranged from 25.7 to 36.3^{o}C ($\underline{M}$ = 32.7 $\pm$ 2.2^{o}C). To determine if temperature of gases within the endotracheal tube had an affect on the OT taken while the tube was in situ, the endotracheal tube temperatures were divided into three equal groups (25.7 to 31.9^{o}C, 32 to 33.9^{o}C, and 34 to 36.3^{o}C) and a one way analysis of variance was done on OT, followed by Scheffe's test (α = .05). (Groups were chosen such that an equal number of patients would be in each group.) There was no significant difference in the OT between the three groups.

Room temperature

Room temperature ranged from 22.2 to 26.7^{o}C ($\underline{M}$ = 24.6 $\pm$ 1.0^{o}C). To determine if room temperature had an affect on the difference between OT with and without an endotracheal tube, room temperature was divided into three equal groups (22.2 to 23.9^{o}C, 24.0 to 24.9^{o}C, and 25.0 to 26.7^{o}C). (Groups were

chosen such that an equal number of patients would be in each group.) For each group, a gain score between OT with and OT without an endotracheal tube was calculated and a one way analysis of variance was applied, followed by Scheffe's test ($\alpha = .05$). Results revealed no statistically significant difference in the OT dependent on the room temperature.

The results of this study have shown that both the IVAC^{R} (in monitor mode) and Hi-Lo Temp^{R} thermometers have concurrent validity and test-retest reliability over an eight month period. Both ATs and OTs measured with and without an oral endotracheal tube were significantly different. There was no difference in TMTs and RTs measured with and without the oral endotracheal tube. A positive correlation was found between the temperatures measured at all four sites. Further analysis indicated that respiratory rate, mouth position, teeth, room temperature, and temperature within the endotracheal tube did not have an affect on the OT measurement. Patients not entered into the study were no different than those entered in terms of age, sex, and APACHE, however, they were significantly different based on primary reason for admission to the ICU. These results are discussed in the following chapter.

CHAPTER V

DISCUSSION

Temperature monitoring is a very basic part of the nursing assessment of patients in the ICU. Results of this study have revealed that the time-honored adherence by nurses to using the rectal site for temperature monitoring in intubated patients may not be justified. OTs were shown to be significantly different when measured with and without an endotracheal tube, however, the 0.08°C difference is not considered clinically important. This finding is consistent with what has been reported in the literature. As a measure of core temperature, OTs have been shown to be appropriate in most situations. Intubation should no longer be an exclusion criteria for choosing the oral site as the site of choice for monitoring temperatures in orally intubated patients, ready for extubation.

Validity and Reliability of Instruments

It was anticipated that results of the validity and reliability testing of the thermometers would add support to the use of ET for monitoring patient's temperature in the clinical situation. Results of this study revealed that the Hi-Lo^{R} and IVAC^{R} (monitor mode) thermometers are both valid and reliable over a period of eight months. It is important to note that the IVAC^{R} was not valid, although it was reliable when used in steady state, the standard mode used in the clinical situation. The difference between the IVAC^{R} in steady state ranged from 0.37 to 0.48°C (rectal probe) and 0.38 to 0.45°C (oral probe) higher than the standard ($p<.01$). Clinically this temperature difference is of importance if treatment is being initiated or postponed based on a single

temperature measurement. It is recommended that for initiating or postponing treatment, more than one temperature measurement be evaluated and that the temperature not be recorded using the steady state of the IVAC^{R}.

Patient Characteristics

It was understood from the outset that some patients who would be eligible for entry into the study would be missed due to reasons beyond the investigator's control. However, it was expected that the patients missed would be no different than the patients entered, based on biographical data. The patients who were not entered were similar in age, sex, APS, and APACHE score, to patients who were entered into the protocol. The two groups were significantly different ($p<.01$) based on primary reason for admission to the ICU. Patients categorized as neurological as the primary reason for admission to the ICU were more likely to meet the exclusion criteria than patients from any other category (see Table 4). This difference is reflected in Table 5, with a significant difference ($p<.01$) being present for the primary reason for admission between the patients entered and those not entered. The differences between the patients entered and not entered might be a concern if the reason for admission had an influence on the temperatures measured at the various sites. It is possible that this may limit the generalizability of the results of this study.

Temperature Measurements With and Without an Endotracheal Tube

It was anticipated that findings of this study would not demonstrate a clinically important difference between OT of patients in ICU, with and without an endotracheal tube in situ. More specifically, it was anticipated that OT

might differ significantly with and without the endotracheal tube, but the difference would not reach clinical importance. OT was significantly different ($p<.01$) with and without an endotracheal tube in situ, but the difference of $0.08^{o}C$ is not of clinical importance. Two factors which should be considered when defining a temperature of clinical importance are, 1) the thermometer's accuracy range, and 2) the outcome that the temperature measurement will affect. Consideration of these two factors renders the $0.08^{o}C$ temperature difference as clinically unimportant. At best, standard clinical thermometers register to one-tenth of a degree Celsius. The $0.08^{o}C$ difference would translate to a $0.1^{o}C$ difference on a clinical thermometer, which does not exceed the manufacturer's reported accuracy range of $\pm 0.2^{o}C$. Based on a $0.1^{o}C$ difference in temperature, treatment would never be initiated or postponed. A third argument which supports $0.08^{o}C$ as not being clinically important is data presented by Holdcroft (1980): the body temperature is maintained within $\pm 0.2^{o}C$. If this is true, then a $0.1^{o}C$ difference would fall within the "normal" maintenance range. This study supports the conclusion stated by Cashion and Cason (1984), based on a study comparing oral and rectal temperature differences in patients pre and post intubation. They concluded that clinically accurate OT measurements can be obtained from orally intubated patients.

As expected, no difference was found between the TMT and RT recorded with and without an endotracheal tube. AT suggested a warming trend from before the endotracheal tube was removed to afterwards ($\underline{M}$ diff = $-0.12^{o}C$). This difference was significant and could be due to a true warming affect due to the length of time the arm was held against the chest, thereby decreasing any

environmental influences that may have affected the AT.

The range in temperature differences between the various sites supports the evidence that a conversion factor does not exist that allows one to convert temperatures recorded at one site to those that would have been recorded at another. Cork, Vaughan, and Humphrey (1983) reported that AT measurements were lower than TMT (range = 1.5 to 1.9°C). Results of this study show AT as being both lower and higher than TMT (-1.1 to 1.1°C difference between AT and TMT). Nichols et al. (1966) reported an oral - axilla temperature difference of 0 to 4.2°F (2.3°C) and a rectal - oral temperature difference of 0 to 2.8°F (1.5°C). Results of this study vary from those reported by Nichols et al. (1966), with the oral - axilla temperature difference being - 0.5 to 1.0°C and the rectal - oral temperature difference being - 0.7 to 0.9°C. Axilla and tympanic temperatures tended to be lower than oral or rectal temperatures and may be related to environmental influences.

A positive relationship was found between the temperatures recorded at all four sites. These results are similar to those reported in the literature, although the correlation values vary. Kresovich-Wendler et al. (1989) reported a correlation of r = .20 between rectal and oral temperatures. This is much lower than the correlation found by the present study (r = .92). The difference in results may be due to thermometer placement in the mouth. Kresovich-Wendler et al. (1989) did not control for thermometer placement. Terndrup et al. (1989) reported the correlation between the tympanic membrane and rectal temperature as r = .90, which is consistent with the findings of the present study, r = .88. Gibbons (1967) reported a correlation of r = .85 to r = .99 between oral and

tympanic temperatures. These results as well, are consistent with the findings of the present study, r = .88.

Factors which may Influence Oral Temperature

The present study was not designed to examine the following factors and their affect on OT, however, in an attempt to extract as much information as possible, the data was analyzed beyond the main hypotheses. It is therefore important that the following results be viewed with caution. Factors that were examined in relation to OT measurements were teeth, mouth position, temperature within the endotracheal tube, and room temperature. T-tests and analysis of variance were used to evaluate differences in OT based on these factors. In retrospect, it is acknowledged that another way of examining these factors would be to pose a second question and examine the relationship of each factor to OT. Multiple regression techniques could then be used to examine the impact of each factor on the variance in OT. It is further acknowledged that the use of multiple t-tests increases the likelihood of finding a significant difference where none exists.

Teeth

The results of the present study indicate that the presence/absence of teeth does not make a difference on OT measurements. This does not support the suggestion in the literature that the absence of teeth has a lowering affect on OT measurements. Erickson (1976) found that edentulous patients showed the greatest difference between temperatures taken at various positions in the mouth, as compared to patients with teeth. This was a secondary finding and no

statistical testing was applied to the data due to the small number of patients without teeth ($\underline{n} = 4$).

Mouth Position

Results of this study support the findings of Cooper and Abram (1984) that when using the posterior sublingual pocket, mouth position (open versus closed) does not affect OT measurements. This differs from Erickson's (1976) findings, in which a significant difference was found in OT with mouth open or closed. However, it is important to note, that although statistically significant, the clinical importance of the difference (- 0.7 to 1.0°F) was questioned. The difference in results from the present study to Erickson's (1976) may be related to the degree that the mouth was open. Erickson (1976) instructed patients to hold their mouth open, but does not define mouth open. In the present study, mouth open was defined as a visible space between the lips.

Respiratory Rate

Based on OT recorded without an endotracheal tube, results of this study are in conflict with those reported by Tandberg and Sklar (1983) and Durham, Swanson and Paulford (1986). Results of this study reported no significant difference between OT measurements when respiratory rate was ≤ 20 and > 20. The difference was $\pm$ 0.31, with the temperature of the group with respiratory rate > 20 being higher, opposite to what the literature suggests. An explanation for the differences in results may be related to whether or not patients were mouth breathing. Kresovich-Wendler et al. (1989) reported that when examined in isolation, respiratory rate had a significant effect on OT measurements. However, when examined using a backward elimination step-wise regression model,

respiratory rate lost its significance and the variables that contributed most to the variance in OT were heart rate and mouth breathing. The present study did not monitor mouth breathing, and although patients had their mouth open, it cannot be assumed that they were mouth breathing. (Open mouth was defined as a visible space between the lips.)

Temperature Within the Endotracheal Tube

The temperature within the endotracheal tube was not shown to have an affect on the OT measurement. When OT was compared based on the temperature within the endotracheal tube, no significant difference was found. This does not support the notion that the temperature of the gases within the endotracheal tube cause a local heating/cooling affect which can alter the OT. This also refutes the notion that air leaks from around the endotracheal tube would cause a lowering in the OT measurements, since OT were higher with the tube in than with the tube out.

Room Temperature

The present study suggests that the room temperature does not have an affect on the OT measurements recorded with and without an oral endotracheal tube. The room temperature only varied 4.5°C (from 22.2 to 26.7°C). This variation in room temperature might not have been large enough to affect the OT measurements. Perhaps if a much larger variance was present in the room temperature, there may have been an affect on the OT.

In summary, the results of this study support results that have been reported in the literature regarding measuring OTs in intubated patients. Both ATs and OTs measured with and without an oral endotracheal tube were

significantly different, but the difference was not of clinical importance. There was no difference in TMT and RT measured before and after the endotracheal tube was removed. Respiratory rate, presence or absence of teeth, mouth position, temperature within the endotracheal tube and room temperature did not have an affect on OT. As well, a positive relationship was found between the temperatures measured at all four sites.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to determine if there was a difference in OTs measured with and without an oral endotracheal tube in situ, in critically ill patients. This was undertaken to determine if OTs could give accurate results in orally intubated critically ill patients. A secondary purpose was to determine if temperatures taken from other common sites (axilla, tympanic membrane, and rectum) were different when taken while a patient was intubated, as compared to when the patient was extubated.

Conclusions

The present study was conducted to determine if OTs taken on patients who were orally intubated would produce accurate results. The study examined OT taken with and without the oral endotracheal tube in situ and found a significant difference. The difference, 0.08°C, was not considered to be clinically important and the conclusion was drawn that OTs could be taken on patients who were orally intubated and ready for extubation. At the same time, AT, TMT, and RT were examined in relation to the endotracheal tube: The difference in the ATs was significant, while the differences in the TMTs and RTs were not. A positive correlation was found between the temperatures measured at all four sites. Several factors, respiratory rate, mouth position, presence or absence of teeth, room temperature, and temperature within the endotracheal tube were examined and found to have no affect on OT. The IVAC® and Hi-Lo Temp® thermometers were shown to be both valid and reliable over an eight month period.

Implications for Nursing

Results of this investigation have several clinical implications for temperature monitoring practices in intubated patients in the ICU. It is recommended that OT be monitored rather than rectal, axillary, or tympanic membrane temperatures, whenever feasible in "stable" ICU patients. Ideally it is beneficial to take serial temperature measurements using a single route, before, during and after intubation to aid with the assessment and management of care of the patient. With OTs being the most common temperature measurement taken on the general wards, it would be desirable to take OTs throughout the patient's stay in ICU. Since this protocol only examined patients ready for extubation, no conclusions can be drawn about monitoring OTs on patients, throughout their entire stay in ICU. At times, it may be contra-indicated to monitor temperature orally. On these occasions, one of the other sites would be appropriate. If the site used to monitor temperature is the axilla, the probe should be left in place for nine minutes minimum, with the arm held tightly against the chest. (If the IVAC^{R} thermometer is being utilized, it is must be used in monitor mode.)

In relation to the type of thermometer used to measure temperature, it is recommended that electronic thermometers, as opposed to glass, be used in clinical practice. This is strongly supported by the literature, with glass thermometers being less accurate than electronic. If the IVAC^{R} is being used, it is recommended that it be used in monitor mode; if it is used in steady state, it is important to remember that it will record temperatures approximately 0.5^{o}C higher than what they actually are. The FirstTemp^{R}

thermometer appears to be an option for measuring temperatures, but further research is required before it can be recommended.

Limitations

The limitations of this study are:

1. When comparing patients who were and were not entered into the study, a significant difference was found, based on sex and the primary reason for admission to the ICU. This would suggest that a selection bias might have occurred. If sex or primary reason for admission to the ICU affect the OT, then the generalizability of the results is limited.
2. Only patients ready for extubation were included in this study, therefore, generalizability of the findings may be limited to patients ready for extubation.
3. The phenomenon of testing may have affected the temperature measurements recorded in two ways:
   a) The patients had temperatures taken on two separate occasions. It is possible that the patient may have been anxious prior to the protocol procedures and extubation, not knowing what to expect. This may have caused the slight increase in core temperature that was evidenced by the continuous tympanic membrane temperature.
   b) The order in which the temperatures were taken may have contributed to the differences seen in the temperature recorded. Although the order of the temperature measurements was designed to minimize any true temperature change effect, there was time that passed between each measurement. This could have contributed to some of the differences

in temperature between the sites noted. Ideally, temperatures from all sites should have been measured and recorded simultaneously. However, due to financial, personnel and equipment restraints, it was impossible to conduct the experiment in this way.

4. All temperatures were taken on patients with, followed by without an endotracheal tube in situ. Due to the condition of the patients in Intensive Care, there was no way to control for this. Recorded temperature changes from before to after the endotracheal tube was removed, could be reflective of a real change in core temperature due to the time between temperature recordings, or the act of extubation. It was expected that a change in core temperature would be reflected at all sites, but due to the response time in temperature changes at the various sites, this may not have occurred.
5. This protocol did not study patients at various stages of their illness; the patients were generally over the "critical" phase of their illness.
6. The FirstTemp^{R} thermometer was not checked for validity or reliability due to inaccessibility of equipment. Therefore, although the temperatures recorded with this thermometer are similar to the recordings at other sites, it is not known if they are accurate or reliable.
7. The data was analyzed beyond the main hypotheses, therefore, the results regarding factors which may have an affect on the OT should be viewed with caution.

Suggestions for Further Research

The present study has concluded that OT can be monitored accurately using an electronic thermometer, in orally intubated patients that are stable and ready for extubation. It might be hypothesized that OTs could be accurately monitored throughout the patients course in ICU; therefore, this study should be replicated not only for similar patient populations, but also for patients at various stages of their ICU stay. The recording of temperatures from all sites over time, for such patients would further add to our knowledge of criteria for site selection for monitoring temperature.

Relationships between various monitoring sites during profound hypo/hyper-thermia have not been established; nor have relationships between the various sites during heating/cooling. Research should be undertaken to examine the relationship and comparison of temperatures at various sites during hypo/hyper-thermia and procedures of heating and cooling critically ill patients. Research should also be undertaken to examine the affects of fluid, blood, and medications on the temperatures recorded at the various sites since it is not known if or how these treatments affect the various sites in relation to monitoring temperature.

The present study was not adequately designed to examine the effects of mouth position, respiratory rate, teeth, or temperature within the endotracheal tube on OT measurements. It is therefore recommended that further research be done in this area, in critically ill patients. It is believed by the author that OT may in fact be the route of choice when measuring temperature in critically ill patients, rather than rectal, as is the case today.

Temperature monitoring as an aid to assessing a patient's health status has been used for many centuries. Most nurses take temperatures without ever thinking twice, as a matter of routine, acting upon what they read in their introductory text to nursing or what a more experienced nurse transmitted to them. In the ICU, the majority of nurses monitor patient's temperature rectally because that is what they were taught in orientation, other nurses monitor temperature orally in these same patients because they prefer oral to rectal temperatures. This study offers an initial scientific base to support the use of oral temperatures in orally intubated critically ill patients.

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APPENDIX A

Sample size calculation*

$$d_4' = \frac{m_x - m_y}{\sigma} = \frac{0.2}{0.73} = .27$$

$m_x - m_y$ = difference to detect

$$d = \frac{d_4'}{\sqrt{1 - r}} = \frac{0.27}{\sqrt{1 - .80}} = .604$$

d= effect size

$r_{i.e}$= estimated correlation between OT with and without an oral endotracheal tube

$1 - \beta = 0.80$

$\alpha_2 = 0.01$

$$n = \frac{n_{10}}{100d^2} + 1 = \frac{2338}{100(.604)^2} + 1 = 65$$

based on Cohen, 1969, ch.2

APPENDIX B

Data collection form

Date_____ Subject #___ Initials_____ ID_____

Age____ Sex_____ Diagnosis_____

Primary indication for admission to ICU

___respiratory ___metabolic
___neurological ___gastrointestinal
___cardiovascular ___hematological
___renal

APACHE APS___ CHE___ Age___ Total___

INCLUSION CRITERIA

___> 17 year
___English speaking
___Order to extubate
___Consent

EXCLUSION CRITERIA

___Ear/oral/axilla/rectal infection or surgery
___Rectal anastomosis
___Sclerosed hemorrhoids
___Middle fossa #
___Fluid challenge/bld in past 30m
___local heating/cooling cin 30m
___vasodilator in past 30m

Teeth: Pre: yes___ no___ NG yes___ no___
Post: yes___ no___ location_____

Site of oral endotube_____ Temp of OETT_____

Site: Con Tymp: rt_____ lt_____
Axilla: rt_____ lt_____
Tympanic: rt_____ lt_____
Oral: rt_____ lt_____

Cont Probe in (Time)_____ Room Temperature_____

APPENDIX B cont'd

Intubated Temperatures

Time	CIMT	Site	Temp
		AT	
		TMT	
		OT	
		RT	

Mouth open___ closed___

RR_____

Extubated Temperatures

Time	CIMT	Site	Temp
		AT	
		TMT	
		OT	
		RT	

Mouth open____ closed____

RR_____ Oxygen_____

Extubation Time _____ Temp During Extubation _____

APPENDIX C

Budget

1. Personnel		Amount
a) Principal Investigator		nil
b) Research Assistant @ 1 hour/subject		
75 subjects x $16.00/subject	= 1200.00	1404.00
17% benefits	= 204.00	
c) typist		
20 hours x $12.00/hour	= 240.00	280.00
17% benefits	= 40.80	
2. Equipment		
a) IVAC thermometer/probe covers (donated)		nil
b) FirstTemp/probe covers (donated)		nil
c) Hi-Lo Temp/probes (donated)		nil
d) Guidline (donated)		nil
3. Supplies/Services/Travel		
a) photocopying		70.00
protocol for ethics committee	100x.10/ea	
data collection forms	100x.10/ea	
consent forms	200x.10/ea	
ten copies final report	200x.10/ea	
miscellaneous	100x.10/ea	

APPENDIX C cont'd

b) statistical consultation	
10 hours x $60.00/hr	600.00
c) computer time	100.00
d) travel to present research findings	1000.00
e) reprints of published article	100.00
Total	3554.00

APPENDIX D

Time Line

Date	Activity
July 1988	Consult statistician
July 29 1988	Submit proposal to thesis committee
August 4 1988	Submit proposal to Nursing Faculty
August 12 1988	Oral Defence Revisions
August 18 1988	Nursing Faculty Review
August 25 1988	Submit proposal to RAH
September 8 1988	RAH Ethics Review
September 1988	Final protocol revisions
December 1988	Conduct pilot study Modifications as necessary
January-August 1989	Data collection
September-November 1989	Data analysis
November-December 1989	Write research report
December 1989	Final Defence Revisions as required

APPENDIX E

INFORMED CONSENT FOR THE RESEARCH STUDY TITLED:

A Comparison of Oral, Axillary, Rectal, and Tympanic Membrane Temperatures of Patients in the Intensive Care Unit, With and Without an Oral Endotracheal Tube.

Principal Investigator: Elsie Konopad RN, BScN, MN Candidate
Thesis Supervisor: Dr. J Kerr PhD
Committee Members: Dr. T Nosworthy MD MSc MPH
Dr. M Grace PhD PEng

Most of the patients admitted to Intensive Care require the insertion of a tube into their windpipe to help them with their breathing. When patients have this tube in, it is believed that oral temperatures are not accurate and therefore, the nurses take the patients' temperatures rectally. In some situations it is necessary to take the temperature axillary (underarm), although this is not considered very accurate. Tympanic membrane (ear drum) temperature monitoring is becoming more popular for measuring temperatures. The purpose of this study is to compare the oral, axillary (underarm), rectal, and tympanic membrane (ear drum) temperatures of patients while they have the breathing tube in, with those same temperatures after the tube has been removed.

The study will take approximately one hour or less. If you agree to participate in this study, a temperature probe will be inserted into your ear. This probe will remain in place until the study is finished. You will be required to lie still for 10-20 minutes, during which time it is asked that you not talk or sit up; or change position. Following the 10-20 minute period, you will have your oral, axillary (underarm), rectal, and tympanic membrane (ear drum) temperatures taken. The breathing tube will be removed following the doctors order. Your temperatures (oral, axillary (underarm), rectal, and tympanic membrane (ear drum)) will be taken one more time, after a quiet period of 10-20 minutes. No further time commitment is required.

There may not be any particular benefits to you at this time by participating in this study. However, if it is found that oral temperatures in patients with tubes, are no different than those in patients without tubes, your participation may be beneficial to other patients in the future. Participating in this study exposes you to no added risks other than those associated with routine temperature monitoring.

Participation in this study is voluntary and I understand that I am free to drop out of the study at any time. I further understand that if I do not join the study, or if I drop out at any time, the quality of my care will not change.

Elsie Konopad has explained the purpose of this study to me, as well as the risks and benefits involved. Any questions that I had regarding the study have been answered.

Appendix E cont'd

I understand that no promises have been made to me as to the results from the procedure outlined. I know that I may ask now, or in the future, any questions about the study procedures. I have been assured that personal records relating to this protocol will be kept confidential and that no information will be released or printed that would disclose my personal identity without my permission. In addition, the forms with information regarding this study, will not have my name or hospital number on them.

I agree to participate in this study of temperature monitoring and have received a copy of this consent form.

Date _____ Signature _____
Patient

Witness: _____

Investigator: _____

If you have any questions about this study at any time, please contact:

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